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WSEG REPORT NO. 45

POTENTIAL CONTRIBUTION OF NIKE-ZEUS TO DEFENSE OF THE U.S. POPULATION AND ITS INDUSTRIAL BASE, AND THE U.S. RETALIATORY SYSTEM

23 September 1959

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POTENTIAL CONTRIBUTION OF NIKE-ZEUS TO DEFENSE OF THE U.S. POPULATION AND ITS INDUSTRIAL BASE, AND THE U.S. RETALIATORY SYSTEM

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POTENTIAL CONTRIBUTION OF NIKE-ZEUS TO DEFENSE OF THE U.S. POPULATION AND ITS INDUSTRIAL BASE, AND THE U.S. RETALIATORY SYSTEM

(U) STATEMENT OF THE PROBLEM

1. The Weapons Systems Evaluation Group has been requested "to evaluate the potential value of the NIKE-ZEUS anti-ballistic missile system in the defense of population centers, retaliatory bases, and other pertinent installations.

2. "The study should assume:

a. Design specifications of the system will be met.

b. A date of availability of the system about 1964.

"The study should develop costs for various levels of defense and, where possible, alternate means of achieving similar objectives should be evaluated."1/

BACKGROUND DISCUSSION

3. The bulk of this Report is devoted to a quantitative analysis of the cost/effectiveness of postulated AICBM active defenses and possible complementary and alternative defense measures. The fundamental requirement for an active AICBM defense in CONUS has been established primarily on grounds other than its cost/effectiveness; thus the results of this paper serve only to indicate how such an active defense can be employed, not whether it should be employed. Previous WSEG studies2/ have concluded that in the budget for CONUS air defense, active AICBM defense should enjoy priority second only to Early Warning against bomber and ballistic missile attack. CINCNORAD has stated the same priority as part of

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1/ Director of Defense Research and Engineering, Memorandum for the Director, Weapons Systems Evaluation Group, 10 July 1959, SECRET.

2/ WSEG Report No. 33 (CADOP 56-66) and WSEG Report No. 30, TOP SECRET.

his policy in the "Commander's Foreword" to NADOP, and his concept has received JCS agreement. WSEG and CINCNORAD reached this conclusion despite knowledge of the high cost and technical difficulty of achieving even a moderate active defense level against ballistic missile attack.

4. The present analysis indicates that an active defense such as could be provided by NIKE-ZEUS can protect selected targets in CONUS against attacks in which only small numbers of warheads arrive simultaneously or in which larger numbers of warheads arrive so spaced in time as to fail to saturate the defenses. Both of these cases are relevant to possible future attacks by the USSR or possibly lesser powers. It is also shown that if the enemy is capable of delivering saturation attacks, either by use of cluster warheads or well-coordinated missile launchings, or if the enemy chooses to exploit fallout in his attacks, that an active defense such as could be provided by NIKE-ZEUS could not, by itself, provide adequate protection to CONUS. This is also true of our anti-bomber defenses, yet did not inhibit our deployment of such defenses. To be sure, achievement of a given level of protection against ballistic missiles may be more expensive than achievement of the same level of protection against bombers, but this cannot deny the political, psychological and military necessity for providing some active protection to the major elements of our industrial and military potential. NIKE-ZEUS is the only complete weapon system under development at this time for defense against ballistic missiles.

SCOPE AND ASSUMPTIONS

5. The primary purpose of any active defense system, or indeed, any military weapons system of the U.S. is to aid the U.S. in maintaining its deterrent to war. In the event

deterrence fails, the purpose is to aid in achieving a military victory and to assist in insuring the national survival. Against these goals must be measured the contribution of any offensive or defensive weapons system.

6. While a sizeable portion of the discussion in this Report is pertinent to many existent or conceived defensive weapons, it is applied exclusively to the NIKE-ZEUS anti-ballistic missile system in order to measure its particular contribution to the achievement of the goals of the U.S. Since NIKE-ZEUS is the only AICBM defense system under development, no comparison will be made in this study with any competitive system. Rather, other means of realizing U.S. policy are considered to ascertain whether there may exist competitive or more efficient methods to achieve the same national goals.

7. For purposes of analysis, this study considers the possible contribution of the NIKE-ZEUS weapons system or possible alternatives toward:

a. Increasing the amount of our retaliatory forces that can survive an enemy attack,

b. Increasing the number of people that can be preserved from the effects of nuclear attack, and, finally,

c. Increasing the portion of our military, political and industrial structure that can survive an attack to the extent that this surviving industrial base can be used by the surviving population to successfully pursue a war or to insure their survival as a nation.

8. In this general framework, then, examination is made of the potential contribution of NIKE-ZEUS to the achievement of

such goals by deployments to population centers, retaliatory bases, and other pertinent installations. The time period of interest is taken as 1965-1970.

METHOD OF STUDY

9. In considering the problem of defending population or population centers, attention is first focused on the vulnerability of population to the direct effects of nuclear attack (blast, thermal, and nuclear radiation, including fallout). NIKE-ZEUS is examined as it might contribute to the defense of a population no better prepared than today's U.S. population to withstand the effects of a nuclear attack. In this context, fallout shelters are examined to gauge their possible contribution in saving population relative to the active defense of population centers by NIKE-ZEUS. For unprepared population, first priority is given to the task of increasing the numbers of people that can survive a nuclear attack because the effects of fallout so much overshadow the effects of blast for an attack involving many ground burst nuclear weapons that the vulnerability of the population far exceeds the vulnerability of the industrial plant it uses.

10. In the case that adequate fallout sheltering exists, the potential contribution of ZEUS to the protection both of population and the industrial plant is examined. Since enemy reaction to any defensive measures must be anticipated, it is pointed out that confidence in the attainment of any level of protection by the defense must reside to a large extent in the exchange rate between offense and defense -- a measure of relative costs to maintain the initial balance if a form of armament race ensues. This exchange rate concept is useful to the extent that other than economic limitations are

not exceeded. Conditions under which ZEUS provides a favorable initial exchange rate vis-a-vis enemy ICBM's are pointed out. Finally, the dependence of an assay of the potential contribution of ZEUS defense on the evaluation of the enemy threat is emphasized.

11. The potential contribution of ZEUS to the defense of the CONUS-based retaliatory system is next considered. Other retaliatory systems which are not candidates for ZEUS defense, such as POLARIS, are not considered. In the analyses used in this section the ZEUS battery is assumed to perform at its maximum design capability to establish limiting case arguments. To examine whether any measure is competitive with ZEUS defense of hardened missile sites (typified by the MINUTEMAN concept) to increase the number expected to survive an enemy attack, the alternative of increased MINUTEMAN force levels is considered. Mobility or additional hardening are not examined in detail since reliable cost information is lacking, but either might be more desirable means of increasing the numbers of MINUTEMAN expected to survive than increased force levels of presently conceived fixed [redacted] MINUTEMAN, depending on the precise enemy threat.

12. Defense of ATLAS and TITAN sites is also considered, but in somewhat less detail.

13. Defense of SAC manned bomber bases is examined principally in the context of a successfully operational BMEWS. In this case the vulnerability of the alert portion of the force is considered to arise principally from insufficient warning of sea-launched ballistic missile attack and the potential contribution of ZEUS at its maximum design capability is evaluated in this light. Other measures to increase

the number of surviving SAC bombers are discussed, including air alert and infrared (IR) warning. Protection of air bases as such or the non-alert SAC bomber force is also examined.

14. Other installations important to the operation of the U.S. retaliatory force or, more generally, to the conduct of a war are grouped under the term "control centers" for purposes of this discussion. Such installations share characteristics of retaliatory bases as likely direct targets under most attacks and of population centers in that they must be preserved over longer durations of time in contrast, perhaps, to installations containing alert or quick reacting forces.

15. The detailed development of these topics is taken up in the Enclosures to this Report which divide the material as follows:

Enclosure "A": NIKE-ZEUS System Characteristics,

Enclosure "B": The Potential Contribution of the NIKE-ZEUS System in Defense of Population and Population Centers,

Enclosure "C": The Potential Contribution of NIKE-ZEUS in Defense of the Retaliatory System,

Enclosure "D": Expected Capabilities of NIKE-ZEUS Firing Unit Against Possible ICBM and IRBM Threats.

CONCLUSIONS

TECHNICAL CAPABILITIES OF THE NIKE-ZEUS SYSTEM

16. The estimated effectiveness of the current design of the NIKE-ZEUS system against a ballistic missile attack is quite sensitive to the technical and tactical threat assumed. Assuming the design specifications are met the following conclusions result:

a. The effectiveness of a NIKE-ZEUS battery is high against an attack which consists of single-weapon warheads and discriminable decoys with at most three warheads arriving within about a thirty-second period.

b. The effectiveness of a NIKE-ZEUS battery is considerably poorer against an attack which consists of single-weapon warheads and non-discriminable decoys because saturation is more easily achieved and the anti-missile complement is quickly depleted.

c. The effectiveness of a NIKE-ZEUS battery is negligible against an attack which consists of cluster warheads because saturation is practically assured and/or the anti-missile complement is quickly depleted.

17. It is still uncertain whether non-discriminable decoys, weighing appreciably less than the actual warhead, are possible.

18. Cluster warheads appear technically feasible for the U.S. today, and are under consideration for advanced U.S. Ballistic Missile Systems. The capability of the USSR to develop such warheads by 1965 has not been evaluated by WSEG. However, developments along these lines do not appear unreasonable.

CONTRIBUTION PRIOR TO HOSTILITIES

19. NIKE-ZEUS contributes to the strategic posture prior to initiation of an attack to the extent that:

a. It increases the USSR's tactical and technical requirements.

b. It denies the USSR complete freedom of choice in planning and executing his attack.

DEFENSE OF POPULATION AND INDUSTRY

20. To survive a nuclear attack; the urban population must be protected against both fallout and the other nuclear effects. Rural population requires principally fallout protection.

21. Since fallout dominates other direct weapon effects, protection against fallout alone saves more lives than protection against the other direct effects alone. For comparable expenditures, fallout shelters are considerably more effective and reliable than a NIKE-ZEUS system for the short term protection of the population of the U.S. from the direct effects of a nuclear attack. The problems of long-term survival were not studied. Justification of NIKE-ZEUS for population protection alone, without a decision to implement a fallout shelter program, must rest principally on political or psychological grounds.

22. Industry located in urban centers requires active defense if it is to survive. To the extent that this industry is required for national survival following attack, it must be defended. These requirements for national survival have not been studied.

DEFENSE OF CONUS-BASED RETALIATORY FORCES

Manned Bombers

23. Provided that BMEWS achieves approximate design characteristics, the ground alert force may require no active defense against ICBM attack. Defense of non-alert forces may be desired.

24. Against a sea-launched ballistic missile attack, tactical warning appears marginal. In comparison to a massive

ICBM attack, it is likely that the effectiveness of NIKE-ZEUS against a sea-launched ballistic missile attack will be higher because warhead arrival rates are probably below saturation rates and sophisticated decoys, etc. are less likely. Furthermore, if the enemy increases his submarine forces to overcome NIKE-ZEUS it would increase the probability of his early detection by U.S. ASW forces.

Ballistic Missiles

25. Based on present schedules and costs for MINUTEMAN and NIKE-ZEUS, increases in force levels of MINUTEMAN missiles provide a surer and cheaper method (than NIKE-ZEUS defense of a smaller number of MINUTEMAN) to maintain confidence that a given number of missiles will survive attack. A mobile system or increased hardening may also attain the objective of increased force survival, without increasing force levels.

26. Similar analyses for ATLAS hardened to [redacted] or TITAN indicate that NIKE-ZEUS is cheaper than increased force levels only if the enemy does not successfully employ penetration aids.

SUMMARY CONCLUSION

27. Achievement of a given level of protection against ballistic missiles may be more costly than achievement of the same level of protection against bombers, but this cannot deny the political, psychological and military necessity for providing some active protection to the major elements of our industrial and military potential.

DISCUSSION

INTRODUCTION

28. The discussion that follows, after a brief description of the NIKE-ZEUS system itself, initially compartmentalizes

the potential contributions of ZEUS defense. Its possible contribution to defense of population and population centers is first examined. Then the question of its potential value to defense of the retaliatory force is considered. Only after this are the possible interactions given attention, whereby ZEUS may render a simultaneous contribution to both missions of defense, perhaps a unique quality not shared by the competitors considered in the foregoing analyses. This seems a valid way to limit the discussions initially since situations where ZEUS can provide a real contribution to either purpose must first be found before the question of multi-contribution can capably be approached.

BRIEF DESCRIPTION OF THE NIKE-ZEUS SYSTEM

29. The principal components of the NIKE-ZEUS anti-ballistic missile defense system are the local defense centers (each with a local acquisition radar (LAR)) which can coordinate and assign multiple ZEUS batteries consisting of ZEUS anti-missile missiles, target-tracking radars (TTR's) to each of which is slaved a decoy discrimination radar (DDR), and missile-tracking radars (MTR's). Included in the proposed ZEUS system are also several forward acquisition radars (FAR's) intended to increase the system's capabilities against ICBM attack from the north by earlier acquisition of incoming missiles. Enclosure "A" presents a detailed description of the NIKE-ZEUS system as presently proposed. A nominal battery configuration[3] has been chosen for discussion in this study. It is made up of three TTR's (including one DDR per TTR), ten MTR's, and fifty ZEUS missiles.

3/ Currently used in most costing studies. The conclusions of this Report are not felt to be restricted in any way by the choice of this nominal battery for discussion.

DEFENSE OF POPULATION AND POPULATION CENTERS

30. The concentrations of population and industrial worth found in the larger U.S. cities are fitting elements of the national structure to consider for defense by such a system as NIKE-ZEUS. The vulnerability of the industrial structure to the blast effects of direct nuclear attack is considerable; however, the vulnerability of present-day population[4] to fall-out from direct or indirect attack with ground burst weapons is far greater.[5] Figure 1 taken from Enclosure "B" indicates the fatalities[6] that can be expected in U.S. population from various levels of enemy attack for three targeting doctrines, none of which include an appreciable amount of direct city targeting as such.

a. Targeting for which weapons are delivered uniformly at random over the entire U.S., the results of which resemble those for an attack with major emphasis on retaliatory bases together with some limited targeting of control centers and principal cities.

b. Targeting in which weapons are delivered to regions in proportion to the population in the region, which is roughly typical of an attack concentrated upon the industry and communication and transportation facilities of the U.S.

c. Targeting which seeks to maximize population fatalities by distributing the attacking weapons optimally for this purpose.

4/ This is true of any population without fallout sheltering.

5/ The casualty-producing potential of fallout alone is so large as to encompass the casualties produced in an actual attack by all combined effects. That is, almost all casualties caused by ground burst nuclear weapons could have been caused by the fallout alone.

6/ Ultimate fatalities. The greatest uncertainty in calculations of casualties from fallout is the assumed shielding distribution for the population. No conclusions of this study will change unless nearly an order of magnitude increase in radiation attenuation over that assumed here could be postulated for an unprepared population. It is felt that uncertainty by no more than a factor of two is probable. Of course, such changes in shielding and population behavior assumptions will change the actual number of casualties calculated.

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FIGURE 1

EFFECT OF VARIOUS TARGETING DOCTRINES, ATTACK LEVELS, AND FALLOUT SHELTERS IN TOTAL CASUALTIES IN U.S.A.

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EFFECT OF VARIOUS TARGETING DOCTRINES ATTACK LEVELS, AND FALLOUT SHELTERS ON TOTAL CASUALTIES IN U.S.A.

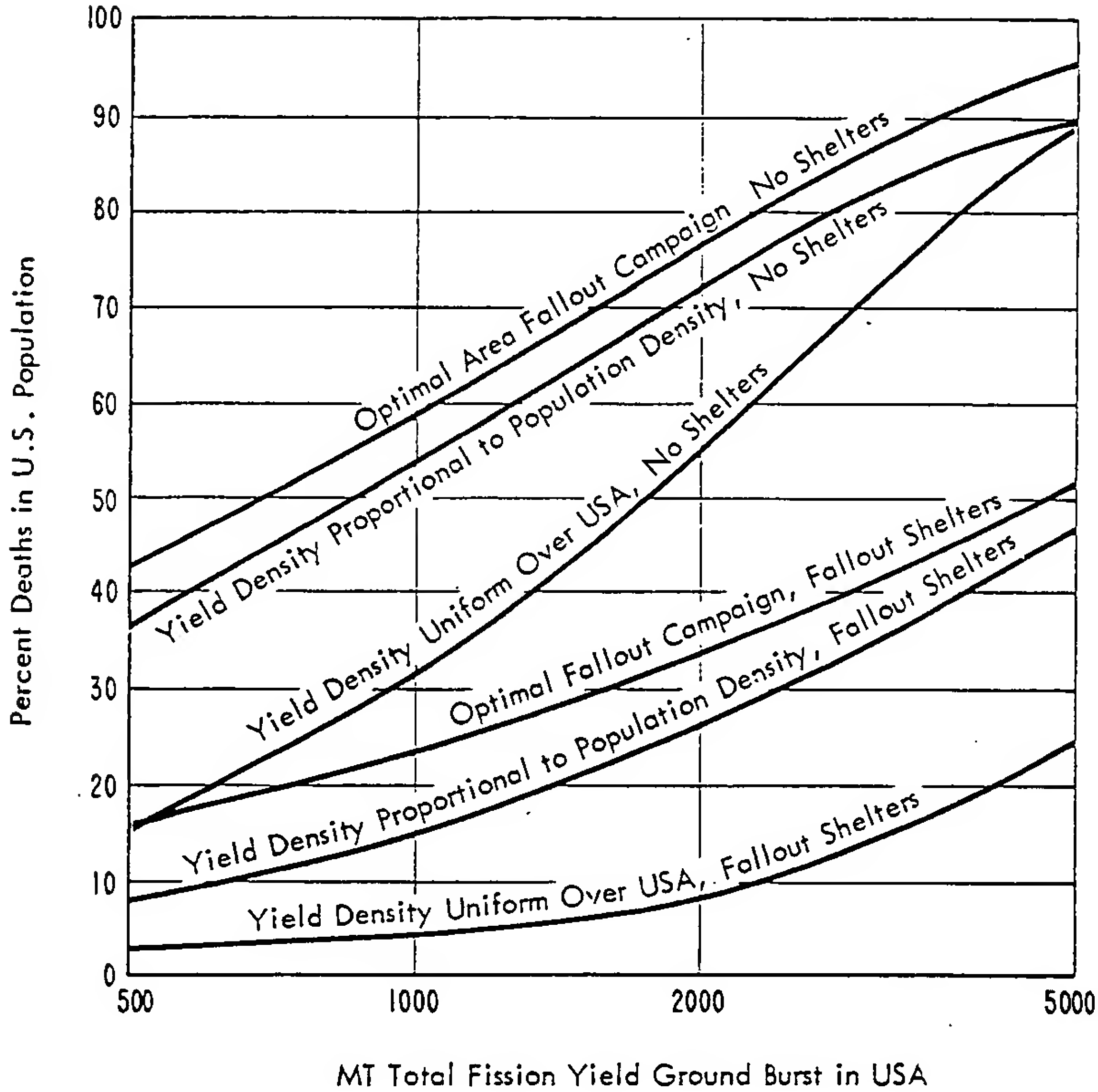

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FIGURE I
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31. While the results shown in Figure 1 are based on a model which assumes that the weapons are delivered at random within each state of the U.S., it is further true that the numbers of fatalities do not change significantly for an unprepared population even if the principal cities within the states are directly targeted for the range of attack levels considered here.

32. To emphasize this point, Figure 2 is presented in which the fatalities for a campaign which attacked cities only, with the objective of maximizing urban fatalities, are compared with the results previously shown in Figure 1 for random attacks proportional to population density and optimized to maximize fatalities.[7] With respect to total casualties the pure city attack is less efficient than either the optimal random fallout campaign or the proportional campaign over most of the range considered. This is due primarily to two causes: first, in the absence of fallout shelters the direct targeting of cities does not cause many more casualties than does random delivery of the same weapons within the same state, and second, the concentration of attack in those states with the most city population has left a much lower level of attack on large segments of the rural population.

33. It is clear that a sizeable attack upon the U.S., with its present civil defense posture, would result in something between a major disaster in the most favorable case shown in Figure 1 of attack on military targets with the lowest yield (500 MT fission yield, implying perhaps 750 to 1000 MT total yield), to total catastrophe for the high yields no matter what the targeting objective.

7/ The direct city targeting campaign cannot validly be compared to the uniform case shown in Figure 1, since the geographical distribution of yield as well as the objective of the attack are so different.

FIGURE 2

COMPARISON OF TOTAL CASUALTIES FROM DIRECT CITY ATTACK WITH RANDOM AREA FALLOUT MODEL (UNPREPARED CASE)

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COMPARISON OF TOTAL CASUALTIES FROM DIRECT CITY ATTACK WITH RANDOM AREA FALLOUT MODEL (UNPREPARED CASE)

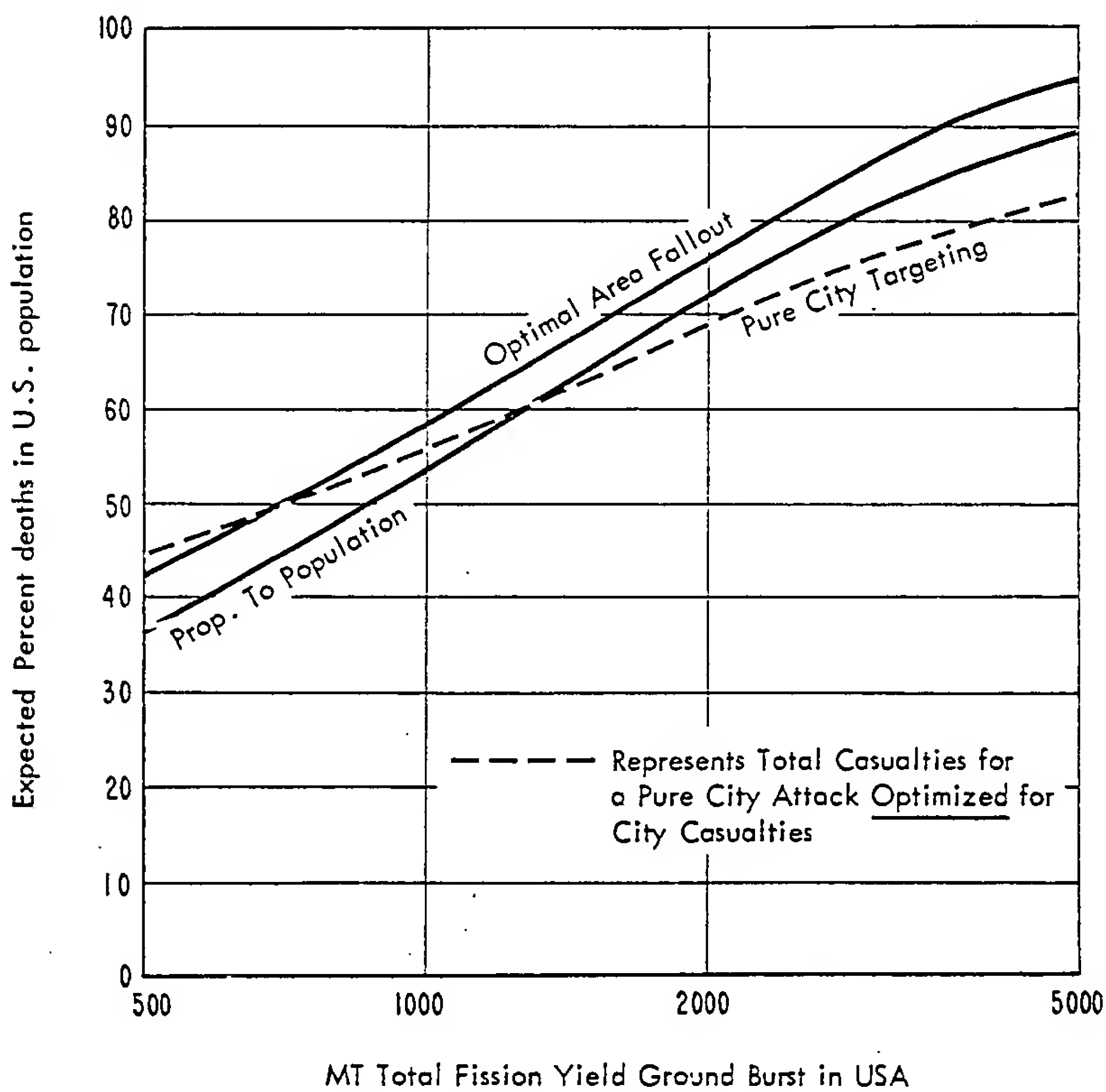

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FIGURE 2
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34. Since an unprepared population is so vulnerable to fallout, whatever the precise details of an enemy attack may be, it seems clear that the defense of such a population must be a defense against fallout as first priority. It seems clear in addition that the defense of such a vulnerable population must take precedence over defense of the industrial base until such time as the disparity in vulnerability (arising roughly from the disparity between the fallout and blast effects of ground burst nuclear weapons) is removed. Stated simply, people themselves are more valuable and at present more vulnerable than the industrial base they use. The potential of fallout shelters is protection of the population as such. The potential of NIKE-ZEUS is protection of both population and the industrial plant. The discussion that follows examines and compares the potential contribution of these weapons to the protection of an unprepared population.

35. A rather elaborate shelter program has been chosen for study. Rough costs of $300 per person sheltered[8] with an effective shielding factor of 33 are conservatively estimated.[9] Analyses of the advance planning, organization, and stockpiling required to care for the survivors and commence recovery, has not been attempted. Neither has any comparison of NIKE-ZEUS and fallout sheltering been attempted beyond their efficiencies in saving population from direct effects of nuclear attack. Indirect effects such as disease, starvation, etc., are not studied. Figure 1 includes curves for a sheltered population to illustrate the appreciable

8/ The shelter program is described in Appendix "B" to Enclosure "B".

9/ The shelter itself has a shielding factor of 5000, but has been degraded to 33 to account for people leaving the shelter as described in Enclosure "B".

savings in lives that can be attained by the program considered. In particular, the effect of the fallout shelters is equivalent in all cases to a reduction of the total fission yield of the attack by a factor of 6.5, as may be verified from Figure 1.

36. Figure 3 illustrates the possible effectiveness of active defense or fallout shelters in saving population of a U.S. city of typical size for the uniform targeting doctrine representative of predominately military targeting. Active defense is assumed to prevent all weapon bursts within a 75-mile radius[10] of the city. For a 2000-MT ground burst fission yield attack, the 75-mile perfect defense achieves a reduction in casualties from 53 per cent to 38 per cent in the unprepared case. This reduction amounts to about 28 per cent of the original expected fatalities. Thus over 70 per cent of the fatalities in this city population can be attributed to the background fallout from weapons burst more than 75 miles from the city.

37. The effect of fallout shelters in protecting city population for this attack is shown in Figure 3 to be far more significant than the active defense alone, while the two combined are still better.

38. These results are of course illustrative for the case of relatively isolated ZEUS defense units. Figure 3 can be interpreted for the case of contiguous cover also. In this case, the graph is entered at a value of "MT total fission yield ground-burst in the U.S.A." corresponding to the number of penetrating warheads.

[10] Nominal coverage of a ZEUS battery. See Enclosure "A" for discussion of coverage.

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FIGURE 3

RELATIVE EFFECTIVENESS OF ACTIVE AND PASSIVE DEFENSE MEASURES FOR PROTECTION OF A SINGLE CITY IN AN ATTACK DIRECTED PREDOMINATELY AT MILITARY TARGETS

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RELATIVE EFFECTIVENESS OF ACTIVE AND PASSIVE DEFENSE MEASURES FOR PROTECTION OF A SINGLE CITY IN AN ATTACK DIRECTED PREDOMINATELY AT MILITARY TARGETS

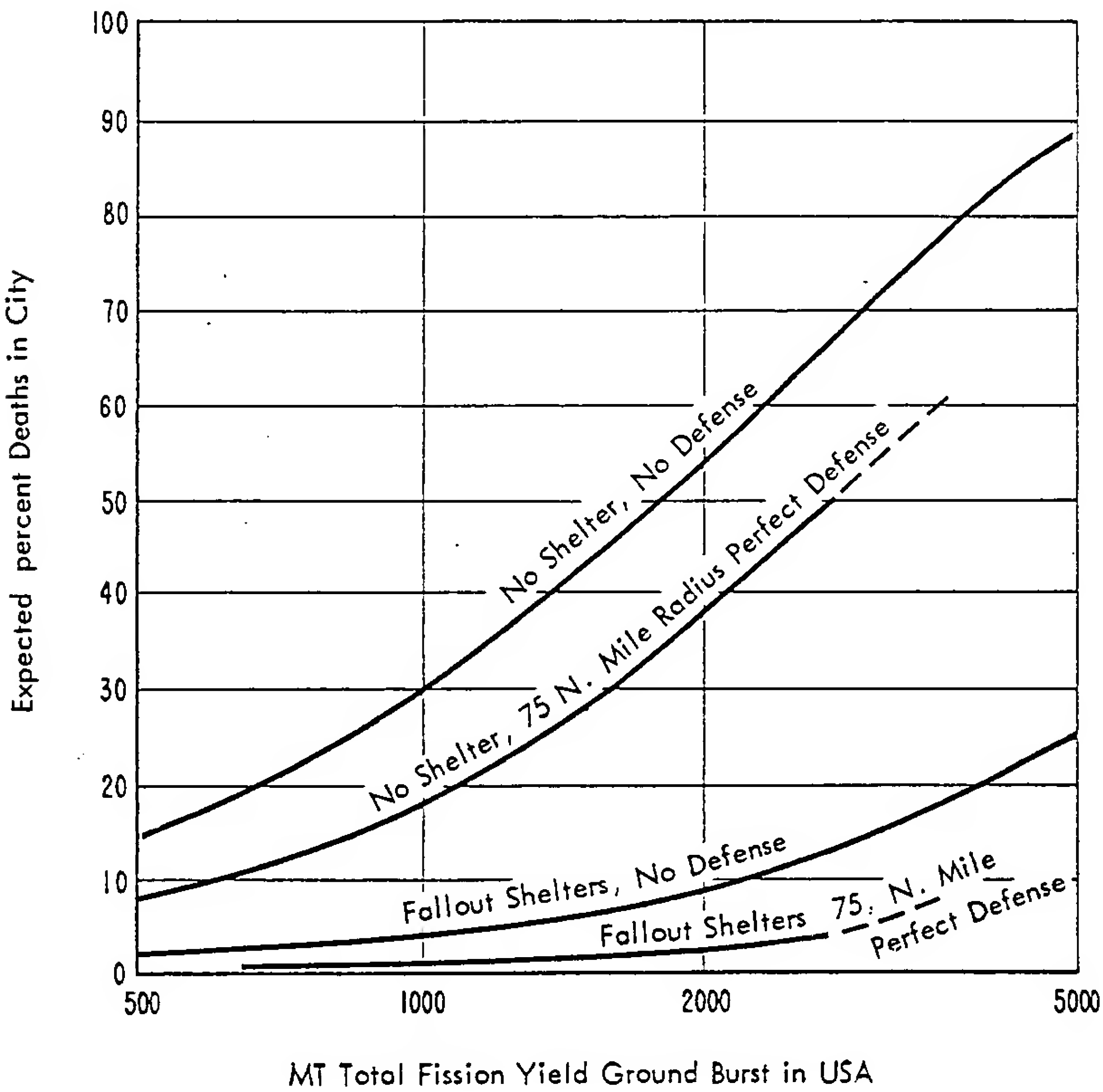

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FIGURE 3
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39. The situation depicted above changes somewhat for the case of a significant amount of direct city targeting to destroy industrial, control, communications, and transportation facilities. The uniform attack model becomes invalid. In addition, a more realistic ZEUS performance than perfect defense should then be considered to obtain useful data.

40. Enclosure "B" discusses the case of a direct attack of a typical size U.S. city by an ICBM containing a cluster warhead. Excluding background radiation from attacks on any other targets, fallout shelters are more efficient means than NIKE-ZEUS defense to save the population of the targeted city from the direct effects of the attack for all but the larger U.S. cities in population (roughly 600,000 or greater population). If background radiation is considered, fallout shelters become more efficient for still larger cities.

41. Even large scale contiguous ZEUS defense could be overcome by an enemy that desired to inflict only heavy population casualties. An example of such an attack, delivering large yields at only two points chosen for penetration, is given in Enclosure "B".

42. On the weight of the preceding evidence, it seems reasonable to judge that, for a given expenditure, fallout shelters from an over-all standpoint are considerably more effective and reliable than a NIKE-ZEUS system for the protection of the population of the U.S. from the direct effects of a nuclear attack.

43. It is also necessary to consider the more general problem of protection of the complex of population and industrial value concentrated in U.S. cities. It must be remembered that the relative superiority of fallout shelters to

ZEUS will decrease as less priority is deemed proper for the mission of saving population as such and more importance is attached to the industrial base. This is true only to the extent that an expected saving in industry is judged worth the attendant loss of lives through neglect of adequate fall-out protection. However, it is felt that these quantities are truly disproportionate at the extremely high casualty levels that can obtain for the magnitude of attack reasonable in 1965-70, as argued previously. A further factor which has large bearing on the confidence that can be put in active defense measures is discussed below. This is the exchange rate -- a measure of the relative costs to offense and defense when both increase their forces to maintain an initial balance. A favorable exchange rate is necessary in order that some measure of confidence can be put on the expected protection provided by a defense system in the real world where defense measures can be expected to produce some reaction on the part of the enemy in the direction of increased offensive force levels to maintain his desired confidence in the result of an attack.

44. In the case that the population is adequately prepared against fallout, then no competitor is evident for NIKE-ZEUS for the task of protection of both population and industry. It therefore becomes necessary to inquire as to the possible effectiveness of the defense that can be provided by the NIKE-ZEUS system.

45. Enclosure "B" describes a model descriptive of a defense system that can be saturated. As indicated in Enclosure "D", a reasonable traffic capability, for simultaneously arriving objects, that may be associated with the nominal NIKE-ZEUS

battery, is four objects. The NIKE-ZEUS system in general is saturable if the enemy is willing to pay the price in missiles required for his desired assurance of penetrating.

46. Enclosure "D" describes the results of a computer simulation of the operation of a ZEUS battery. The number of missiles that must be successfully shot to achieve at least 90 per cent confidence of a penetration for various assumptions of degree of simultaneity, for cluster warheads and for ICBM's with non-discriminable decoys, are given therein.

47. The choice of this high confidence level sets a reasonable price in missiles that must be fixed by the enemy to achieve saturation of a ZEUS battery. Prices obtained for various assumed attack-defense situations are given in Table I, which is taken from Enclosure "B".

TABLE I

INITIAL EXCHANGE RATES BETWEEN ZEUS AND ICBM'S

Case	ICBM's per ZEUS Battery for 90% Reliability of Penetration	Dollar[a] Equivalent of ICBM for Exchange Rate Favoring ZEUS
Simultaneous Arrival ICBM Capability and 10-Element Cluster Whd	0.4	240 million
Simultaneous Arrival, No Cluster	4	24 million
1 Minute Standard Deviation Arrival, 2 Undiscriminated Heavy Decoys	4	24 million
1 Minute Standard Deviation Arrival, No Undiscriminated Heavy Decoys	16	6 million
Slow Arrival, No Decoys	27	3.55 million

a/ The cost slice of a ZEUS battery divided by the exchange rate, based upon a cost of $96 million per ZEUS battery.

48. If for any case shown in the Table it is believed that the USSR could produce an ICBM for less drain upon its economy and resources than the dollar equivalent shown in the table would produce on our economy and resources when spent on ZEUS production, then the initial exchange rate is unfavorable to ZEUS.

49. The exchange rates listed in the Table presume an enemy with full knowledge of the capabilities of a ZEUS battery. Uncertainties can tend to make some of the exchange rates more favorable to the defense, since the enemy could conceivably increase his requirements to cover any uncertainties in ZEUS performance. This is less true in cases involving simple saturation of the tracking capability or missile stockpile capability (the extreme cases of the Table) since the enemy will probably have more certain knowledge of such gross characteristics.

50. The saturation model previously mentioned has been employed with the prices in enemy missiles to achieve penetration from Table I to yield optimal attack-defense configurations for ZEUS defense of U.S. cities wherein the attacker allocates his ballistic missile force to maximize the population fatalities (or the damage to industry)[11] in those cities against a defense deployed to minimize these casualties. The enemy's objective against a city is assumed achieved once the price in missiles to achieve 90 per cent confidence of at least one penetration is exceeded. Since multiple penetrations are expected from the attack levels presupposed for

11/ The value added by war manufacture in a city is roughly proportional to the population of the city. Over a large number of cities the relative population fatalities for different attacks closely approximate the relative amounts of industry destroyed.

90 per cent confidence, this assumption appears quite good.12/ Figure 4 illustrates the behavior typical of all these cases13/ for the threat of ICBM's with ten-element cluster warheads arriving simultaneously.

51. At most levels of attack, the defense can increase with at first no appreciable lowering of the payoff to the enemy until the vicinity of the exchange rate limit is reached (0.4 ICBM's to 1 ZEUS battery in this case). Then increases in defense can lower the payoff appreciably. But, correspondingly, increases in the attack level can raise the payoff appreciably, too. If the enemy can be expected to increase his force levels to counteract increases in defense -- that is, if a form of arms race ensues -- it is valuable to examine these initial exchange rates14/ to determine what confidence the U.S. can put in the protection afforded by this defensive system. The equivalent costs that must be exacted from the enemy to render the exchange rate favorable to the defense are shown in Table I, as previously described.

52. It is clear from an examination of this Table that certain enemy tactics, which appear possibly feasible,15/

12/ Two penetrations are expected from an attack requiring 16 missiles for 90 per cent confidence of a single penetration, for example; 50 per cent confidence of penetration is attained at the 11th missile fired.

13/ Enclosure "B" presents curves illustrative of all cases given in Table I.

14/ Eventually exchange rates become less and less favorable to the defense. Increases in defense beyond the initial level dictated by the initial exchange rate are always less and less efficient because cities are then defended but not attacked since the enemy, moving last, can reallocate his forces to his advantage. However, this region of decreased efficiency occurs at high defense levels relative to the attacking force level which may, perhaps, be an unrealistic situation. This bias for the offense occurs in all situations of a saturable defense, but is not employed in the arguments of this study for the reason cited above.

15/ See Enclosures "B" and "D".

FIGURE 4

CONTOURS OF TOTAL POPULATION OF CITIES WHOSE DEFENSE IS PENETRATED FOR OPTIMAL OFFENSE AND DEFENSE DEPLOYMENTS

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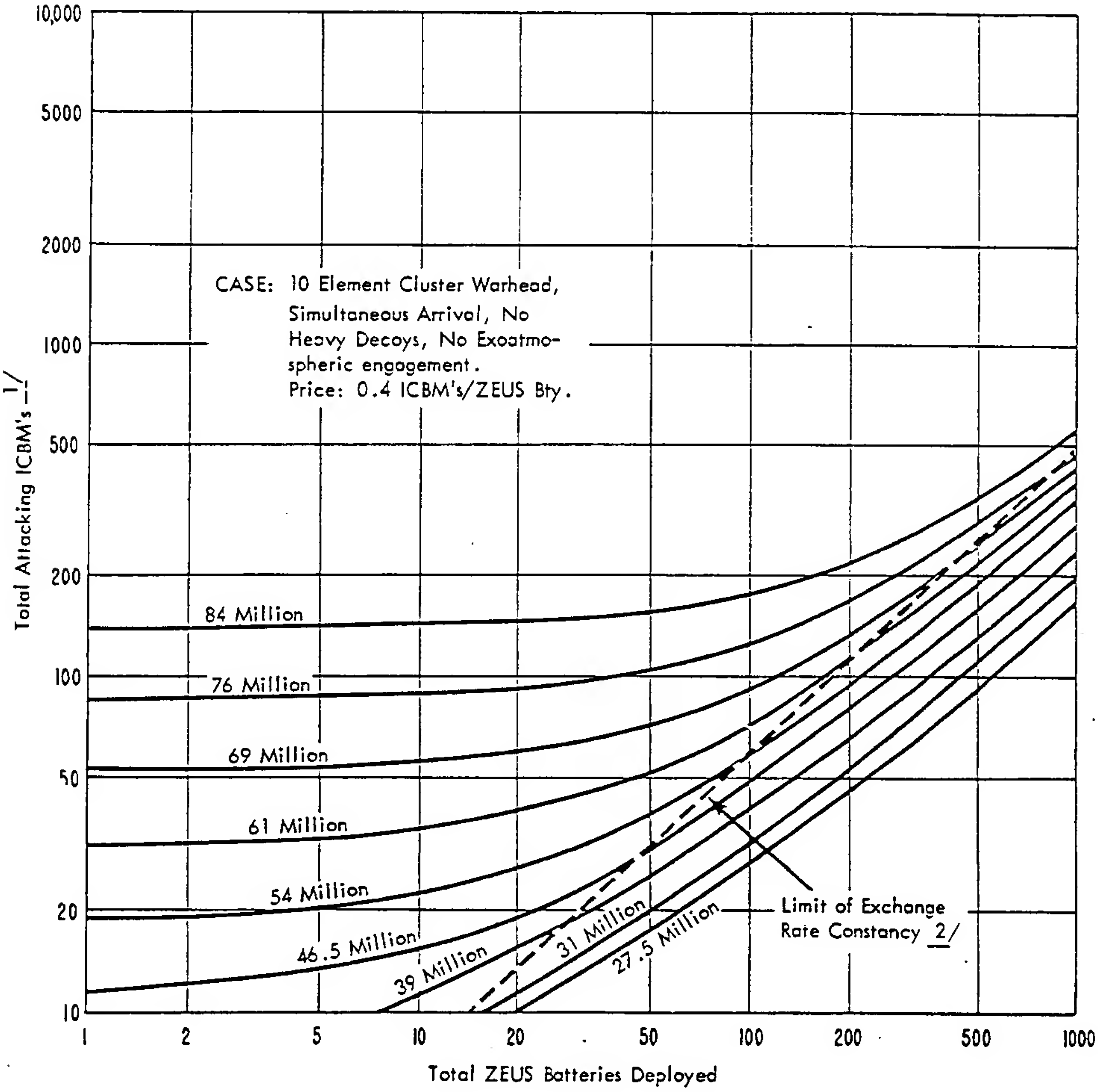
CONTOURS OF TOTAL POPULATION OF CITIES WHOSE DEFENSE IS PENETRATED FOR OPTIMAL OFFENSE AND DEFENSE DEPLOYMENTS



1/ This number should be divided by the estimated reliability to estimate the corresponding total ICBM inventory.

2/ In the region above and the left of this line constant payoff is maintained by all changes in forces whose ratio is the "price."

FIGURE 4
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render the exchange rate particularly unfavorable to the defense (as, for instance, the extreme cluster warhead simultaneous arrival case shown, wherein the impact on Soviet economy would have to exceed the effect an expenditure of $240 million would have on U.S. economy for each missile they produced in order that the defense be favored in an armament race).

53. For these reasons it appears that ZEUS, to the extent that this exchange rate argument holds true,[16] has principal value when the enemy acts less than optimally (in the sense of employing decoys, or attempting to achieve simultaneous arrival, or building cluster warheads). If the enemy miscalculates for whatever reason, then ZEUS can make a real contribution to defense of population and population centers.

54. The evaluation of ZEUS in defense of a prepared population and of population centers thus reduces essentially to an evaluation of the enemy threat. Unless a favorable exchange rate can be postulated or some limit other than economic be put upon enemy capability, then no confidence can be placed in the potential protection afforded by NIKE-ZEUS defense.

55. Some caution should be exercised in applying exchange rate arguments to cities or other largely non-military targets. Such targets may be of much greater importance to the defender then the attacker both because of their population and their industrial installations, and therefore may

[16] The limits of validity of the exchange rate argument must be realized. If increases in enemy force levels are impractical beyond certain limits set by other than purely economic factors such as limited availability of launching facilities, inability to coordinate a larger force, or any such reason, then, of course, the defense can realize an advantage if no such limits exist for it.

be worth defending even at an unfavorable exchange rate. For instance, if the enemy miscalculates and plans a pre-emptive strike intended to nullify our retaliatory force, the destruction of cities might be only a secondary consideration in his plans. If the cities were heavily defended he might well decide against such a heavy expenditure of missiles as would be required to penetrate the defenses. Moreover, such a defense could also be useful as a protection against blackmail by lesser powers. Cities, therefore, may be the most likely candidates for NIKE-ZEUS defense. However, it has been demonstrated that fallout shelters provide a higher confidence of short-term protection for the population of cities at lower cost than NIKE-ZEUS. Therefore, a decision to deploy NIKE-ZEUS for the defense of cities should logically be accompanied by a decision to construct fallout shelters.

DEFENSE OF THE RETALIATORY SYSTEM

56. In this section examination is made of the potential contribution of NIKE-ZEUS to certain elements of the retaliatory system for 1965-70: hardened missile sites of the MINUTEMAN type, ATLAS and TITAN sites, and SAC manned bomber bases. Attention is also given to defense of other pertinent installations which are grouped here under the term "control centers." Inasmuch as certain cities might be regarded as control centers in themselves, that portion of the discussion below will be pertinent to them, also.

57. Throughout the following discussion, the NIKE-ZEUS battery is postulated to perform at the maximum capability provided by its design specifications. The enemy attack is assumed to be a quite poor strategy -- namely, to fire its missiles so slowly that the ZEUS battery can engage each

separately and use its stockpile of fifty missiles in the optimum manner to maximize the number of missiles the enemy must shoot to achieve a given level of confidence of penetration.

58. When the enemy desires 90 per cent confidence of penetration in this postulated situation, he must fire no more than twenty-eight missiles against any NIKE-ZEUS firing doctrine. This then is the assigned price to the enemy that he must pay to penetrate each battery deployed. Fifty per cent confidence of penetration in this case is attained at the seventeenth missile the enemy fires. The expected theoretical maximum price a ZEUS battery could exact is forty enemy missiles (0.80 x 50), but such a defense strategy of one ZEUS missile per incoming ICBM could be profitably employed only when the defense was absolutely sure the ZEUS battery was not the target. If the battery chose this firing doctrine and was targeted, 90 per cent confidence of penetration would be attained by the enemy at about the eleventh missile fired. On the other hand, a lower price than twenty-eight was shown previously for the case that the enemy attempts simultaneous arrival and the ZEUS capability only permits simultaneous handling of four objects. With a reasonable spread in arrival times, a price of only sixteen missiles was exacted for 90 per cent confidence by the enemy when he attempts to saturate the traffic-handling capability of a ZEUS battery. However, the higher price of twenty-eight will be used in the following discussion as representing a maximum ZEUS capability.

59. To ascertain whether any other measure was competitive with ZEUS defense of hardened missile sites such as MINUTEMAN on a cost-effectiveness basis, the alternative of increased

MINUTEMAN force levels was examined. Enclosure "C" estimates that about twenty MINUTEMAN sites could be established at the cost of a single ZEUS battery.[17/] It must therefore be judged which measure can provide the larger number of surviving MINUTEMAN sites from an enemy attack. If each enemy missile could destroy one MINUTEMAN site, the alternatives would be about comparable (28:20). If it is believed that more than one enemy missile would be required by an attacker to achieve his desired confidence of destroying the [redacted] MINUTEMAN site, then the alternative of increased force levels becomes more favorable. In particular, if the enemy is assumed to desire 90 per cent confidence of destroying a MINUTEMAN site with a missile of 8-MT yield and 1-n.mi. CEP, then he would require three per MINUTEMAN site and the ratio becomes 28:60. The disparity becomes much greater if the enemy threat is not so severe as indicated above (especially if accuracy be worse than 1 n.mi.) or if the ZEUS performs at less than its maximum capability, or finally, if the enemy attempts to achieve saturation of the ZEUS battery, perhaps even to the extreme measure of employing cluster warheads. In general, then, increased force levels and ZEUS defense are not at all competitive measures to increase the number of MINUTEMAN sites that survive an enemy attack. Increased force levels are far more efficient.

60. The alternative of mobile MINUTEMAN is discussed briefly in Enclosure "C". If the enemy capability increases until the survivability of fixed [redacted] MINUTEMAN is in doubt, then a mobile system may be considered. The cost ratio to ZEUS is given as a preliminary estimate in

17/ See Enclosure "C" and Enclosure "A" for ZEUS system costs.

Enclosure "C" as ten mobile MINUTEMAN to one ZEUS battery. The efficiency of such a measure to increase the surviving numbers of MINUTEMAN has not been further examined, but in the absence of an efficient and rapid enemy intelligence system, it appears that such a measure would impose much higher requirements in enemy force levels than a ZEUS defense.

61. The alternative of increased hardening of fixed MINUTEMAN sites has not been examined, since cost data are lacking. This measure, like those above, may also be an efficient means to increase the surviving numbers of MINUTEMAN sites. No basis for judgment exists at present.

62. Hardened ATLAS or TITAN sites are considered in Enclosure "C" in the same manner as MINUTEMAN sites were considered. Parity in the enemy force levels imposed by increased force levels and ZEUS defense is noted there at an enemy missile capability of 4 MT and approximately 1 n.mi. CEP, wherein two ZEUS batteries are considered the equivalent in cost of an ATLAS or TITAN squadron of nine missiles at dispersed [redacted] sites. Inasmuch as many of the presently programmed ATLAS and TITAN sites are within the area of a SAC manned bomber base that a ZEUS could defend (within 75 miles), their defense might be thought of as a bonus if ZEUS batteries are deployed to manned bomber bases. However, if the enemy pays the price for penetration to one target he can get the other for no additional penetration price. If the ZEUS be considered to perform at less than its maximum capability, or the enemy threat be judged less than that indicated above, then ZEUS defense is not competitive even with increased force levels for ATLAS or TITAN. For this case in general, though, the situation is far less clear cut than with MINUTEMAN.

63. It is difficult to assess the vulnerability of the SAC manned bomber force through 1965-70. If a successfully operational BMEWS be granted, the principal threat, at least to the alert portion of the force, arises from sea-launched ballistic missiles (SLBM's). Enclosure "C" considers this case in some detail. It appears that, even with infrared warning of 5-10 minutes, ZEUS defense could contribute to saving a portion of the alert force, especially at those bases closer to the sea which could expect much less warning of attack from an infrared system than those further inland. ZEUS deployments to SAC manned bomber bases also could contribute to survival of the bases themselves and perhaps thereby a portion of the non-alert bomber force. If defense of only the alert bomber force (considered here as one third of the total force) is required, then air alert for a limited number of years appears competitive with ZEUS defense[18] and is, of course, a much surer means of preserving the alert force itself.

64. The preceding arguments, based on the exchange rate between offense and defense, are applicable in some part to the situations described in this section. It should be emphasized that enemy reaction to any defensive measure must be anticipated and that little confidence can be placed from a long-range point of view in a defensive system handicapped by an unfavorable exchange rate. However, it appears that practical limits may exist, especially, perhaps, where increases in submarine force levels be considered. In this

18/ Air alert for one third of a 16-wing B-52 force figured on a per base share amounts to $67 million per year from the figures given in Enclosure "C". This is to be compared with the $96 million cost cited for a ZEUS battery. If the equivalent of two ZEUS batteries were required per base (perhaps to cope with a cluster warhead threat), then an equal expenditure could provide almost three years of air alert.

case, too, the initial exchange rate may be favorable to the ZEUS system, especially if such threats as cluster warheads could be considered less serious.

65. Control centers share characteristics of both population centers and retaliatory bases. Like retaliatory bases, they are likely direct targets under any reasonable attack strategy, and like population centers their importance does not decrease with the passage of time, in possible contrast to installations containing alert or quick reacting forces. Control centers for these reasons are perhaps among the more attractive candidates for ZEUS defense, again providing the U.S. can have confidence that its defense enjoys a favorable exchange rate or that other then economic limits restrict increased Soviet force levels. Alternative means of protecting control centers have not been examined.

POSSIBLE MULTIPLE CONTRIBUTIONS OF ZEUS DEFENSE

66. It is reasonable to examine here whether ZEUS defense of portions of the retaliatory force, by reducing the fallout from an enemy attack, can contribute to the defense of population. While such reductions can have real benefit, as shown in an earlier section, it is not evident whether such deployment of a ZEUS system would have actual payoff in reducing population casualties. In particular, if the enemy can be expected to maintain his confidence of destroying a given fraction of the defended retaliatory force by increasing his force levels, then the over-all casualty levels in the event of an attack would be higher, since the ZEUS system would obtain its constant level of attrition, but against a larger attacking force.

67. The inverse case might appear more favorable, whether ZEUS defense of population centers can contribute to defense

of a portion of the retaliatory force, since a number of SAC bases are located within 75 miles of major population centers. As pointed out earlier, however, no bonus accrues if the enemy chooses to pay the price of penetration in order to attack either target, since the other target is then available for no additional penetration price.

68. Other possible interactions have been pointed out in earlier sections but can be reiterated here. Cities considered to be control centers may be valuable candidates for ZEUS defense. Missile sites located within the defended area of a SAC manned bomber base, however, cannot be considered defended beyond the price of penetration for either target.

OTHER CAPABILITIES OF THE ZEUS SYSTEM

69. Capability against air-supported weapons is not included in the presently programmed ZEUS system. A rather interesting capability for an improved ZEUS system is the anti-satellite defense. While possibly desirable, such capability to destroy satellites could probably arise in development without the deployment of the sizeable force levels conceived for defense against ballistic missiles.

70. The potential of the ZEUS acquisition radars to provide early warning might be worth exploring.19/ While BMEWS is probably a more efficient means to obtain warning of ICBM attack, since they are designed for that purpose, the LAR radars of the ZEUS system might be utilized to provide a measure of warning against attack by sea-launched ballistic missiles. However, as pointed out earlier, it is not felt

19/ Enclosure "A" discusses this early warning capability.

that infrared warning of sea-launched ballistic missile attack from the moment of launch could guarantee the safety of the U.S. alert manned bomber force. Therefore, warning still later, from first penetration into LAR coverage, could not guarantee any greater savings. In the case that an infrared warning system does not exist in 1965-70, then any warning provided by the ZEUS system itself to bases further inland could be valuable, if the necessary communication network be established. If an infrared warning system does exist, then the value of ZEUS for warning would lie more in a redundant backup capability to increase insurance of obtaining warning of attack by sea.

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ENCLOSURE "A"

NIKE-ZEUS SYSTEM CHARACTERISTICS

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ENCLOSURE "A"

NIKE-ZEUS SYSTEM CHARACTERISTICS

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FIGURES

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APPENDIX

ENCLOSURE "A"

NIKE-ZEUS SYSTEM CHARACTERISTICS

PROBLEM

1. To develop a statement from Army and other sources of the characteristics of the NIKE-ZEUS system. These characteristics should include those design specifications or expected performance values which are pertinent to an evaluation of the potential uses of the system.

DISCUSSION

GENERAL DESCRIPTION

2. Major Components and Functions. The NIKE-ZEUS system is comprised of missile batteries, acquisition and tracking radars for defense against high performance, high altitude targets. It employs radar tracking data in command guidance throughout the engagement to direct a high performance guided missile designed to intercept ballistic targets with sufficient accuracy to destroy their warheads by nuclear bursts. Acquisition data is provided by a local acquisition radar serving one to ten or more NIKE-ZEUS batteries, each of which may be tens of miles apart. Associated with each local acquisition radar (LAR), and its track-while-scan radar data processor, is a local defense center (LDC). The individual battery includes missiles and launchers, target tracking radars (TTR), missile tracking radars (MTR) and digital guidance computers. A decoy discrimination radar (DDR) is directly associated with and slaved to each target tracking radar. The foregoing system has an autonomous capability against all ICBM and IRBM targets. To attain the full range against the smallest ICBM targets, forward acquisition radars (FAR) are provided and located 300 to 700 miles in advance of the local defended area. Each FAR site has communication links to three or more LDC's. Each NIKE-ZEUS missile is provided with a nuclear warhead and

multi-stage propulsion and utilizes a combination of aerodynamic and reaction control based upon command guidance for intercept within or outside of the atmosphere. The entire NIKE-ZEUS system benefits from early warning received from BMEWS and other warning systems, and in turn is capable of supplying data to NORAD, SAC or other agencies.

3. Typical Anti-ICBM Engagement. The ICBM's are acquired by the forward acquisition radar at a range from 500 to 1,000 n.mi. from that radar, as portrayed in Figure 1. Considering the forward deployment of the radars, it is anticipated that initial detections will occur from 500 to 1,100 miles or more from the area defended, the exact ranges being dependent upon radar cross-section of the targets. Such early detection will provide 200 to 300 seconds of data on each ICBM prior to ZEUS missile launch against each. The forward acquisition radar detects the signals in noise and passes the signals to the acquisition radar data processor. The latter device correlates the signals, initiates tracks on the targets, stores and updates track-while-scan data and predicts the intercept points for up to 200 separate tracks. Those local defense centers capable of engagement are provided ICBM target and intercept position data and battery assignments may be made. The local defense center then acquires these targets with its local acquisition radar and the associated radar data processor. The LAR and its data processor, in turn, provide track-while-scan data on each target (up to about 200) to the displays at the LDC. Data on a specific target also goes to one of the three target intercept computers at the proper battery. At the earliest proper time, a NIKE-ZEUS missile is launched and guided to a predicted intercept by radar command from this (digital) target intercept computer. The command may be based initially on acquisition radar target data. Up to this time, the computers may lump groups of tracks closely spaced together into a "cloud" (such as a target and

FIGURE 1

DESIGN MINIMUM COVERAGE OF NIKE-ZEUS SYSTEM

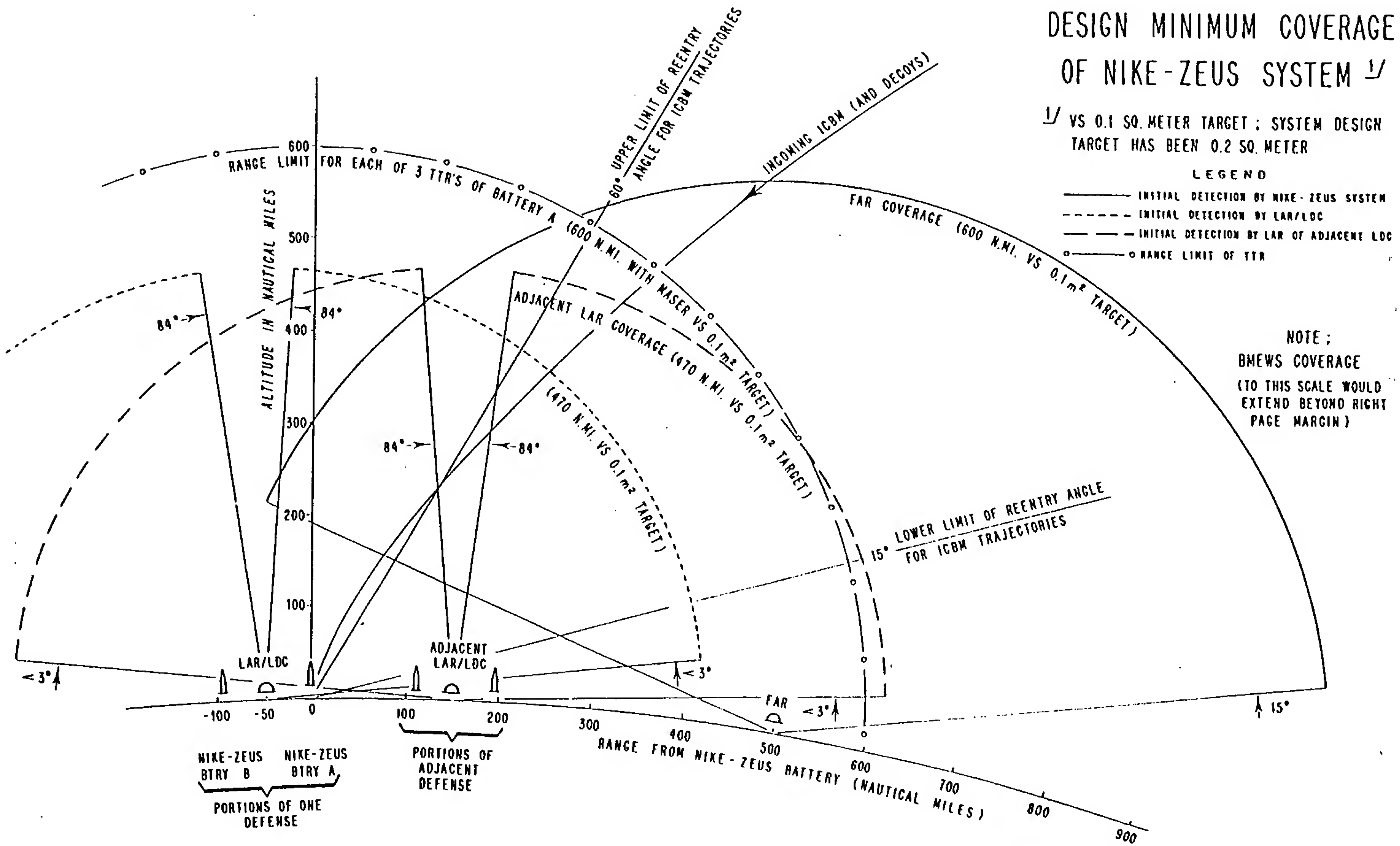

FIGURE 1
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decoy complex). Data on the track in such a case includes the extent of the "cloud". The NIKE-ZEUS missile is tracked continuously from launch until burst and commanded by the missile tracking radar, while the target tracking radar acquires the target or target and decoy "cloud" for purposes of decoy discrimination by the decoy discrimination computer and for generation of precise target data for the target intercept computer. The decoy discrimination radar slaved to the target tracking radar and having a beam width variable with range assists in the decoy discrimination function performed by the decoy discrimination computer. At the proper time the nuclear warhead of the ZEUS missile is detonated by computer command to intercept the target selected from the decoy and target complex.

4. NIKE-ZEUS Battery Composition. To meet the requirements of large traffic capacity, the target tracking radars, missile tracking radars and decoy discrimination radars are numerous. Although the equipment is designed so that a battery may be composed of twice the stated number of any of the key components, the current NIKE-ZEUS battery configuration would include nine missile tracking radars, and a tenth serving as a spare, three target tracking radars and three associated decoy discrimination radars in each battery. Thus up to three groups of targets at the same elevation and azimuth could be tracked simultaneously by each battery. The missile tracker unit time shares the output of the three target intercept computers at each battery. Characteristics of the NIKE-ZEUS radars are presented in Table I.

TABLE I

NIKE-ZEUS SYSTEM RADAR CHARACTERISTICS

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TABLE I

NIKE-ZEUS SYSTEM RADAR CHARACTERISTICS

CHARACTERISTIC	RADAR FAR	LAR	TTR	DDR	MTR
Type			(Monopulse)	(Monopulse)	(Monopulse)
Effective Range a/ (n.mi.)					
1.0 sq m tgt	1020	830			
0.2 sq m tgt	710	540			
0.1 sq m tgt	600	460	± 300 (with TWT) 600 (with MASER)	300(with MASER)	± 200
0.01 sq m tgt			360 (with MASER)	n/	
Accuracy					
Range σ(yds)	250	250	5	40 m/	5
Angles σ(mils)	2 (TWS)	2 (TWS)	0.17 b/		0.17 b/
Coverage Limits					
Elevation (°)	15 to 84	<3 to 84	0 to 90 c/ (No limit)	0 to 90	<0 to 90
Azimuth (°)	0 to 360	0 to 360	0 to 360	0 to 360	0 to 360
Data Interval (sec)	5	2	N/A	N/A	N/A
Target Velocity Limit (ft/sec)			27,000	27,000	12,000 d/
Frequency (mc/sec)	405 to 495	495 to 605	5500 ± 250	1270-1400	8500 to 9600
Band	UHF	UHF	C	L	X
Wave Length (cm)	74 to 61	61 to 50	5.5	20	3.5 to 3.1
Power, Peak	10 megw (ea of 3)	10 megw (ea of 3)	10 megw	20 megw n/	300 kw
Average Power (kw)	600 (ea of 3)	600 (ea of 3)	5		
Transmitter Type	3 Klystrons	3 Klystrons	2 Sperry Klystron e/		#5780 Magnetron
Pulse Rate (prf)	120 pps	150 pps	100 pps	100 pps	(160 gps x 9 pulses)/sec f/
Pulse Width (μ sec)	500	500	5	20 n/	0.25
Refined by CHIRP (μ sec)	4	4	0.1		(0.25)
Duty Cycle	0.06	0.06	0.0005		0.00036
Transmitting Antenna			Cassegranian		Cassegranian
Aperture (ft)	2½ x 120 (ea of 3)	2 x 80 (ea of 3)	22 diam	8	4 diam
Gain (db)	24.6	24.5	49		38
Beam Width (deg)	60 Vert x 1½ Horiz g/	80 x 1½	0.6 h/	5 to 20 j/	2.0
Receiving Antenna	Luneberg Hemisphere	Luneberg Hemisphere	Cassegranian		Cassegranian
Aperture (diam, ft)	120	80	22	8	4
Ground Plane (diam, ft)	460	600	N/A	N/A	N/A
Gain (db)	42.5	40	49		38
Beam Size (deg)	1½ x 1½ i/	1½ x 1½ i/	0.6	5 to 20 j/	2.0
Radome (diam, ft)	150	~ 100 k/	40		13
Receivers (No. of)	486	486	1	1	1
Noise Figure (db)	3.5	3.5	5.0 l/		9.0
Type	MAVAR	MAVAR	TWT	MASER	Xtl Rcvr
Antenna Rotation Rate (rpm)	4	10	N/A	N/A	N/A

a/ Range for 90% probability of detection on a single scan; cumulative probability ~ 100% beyond these ranges.
b/ Error components are: 0.1 mils dynamic, 0.1 mils boresight; and 0.1 mils data takeoff.
c/ TTR provides Automatic Range Scan ± 5000 yd from LAR data point.
d/ For missile; tracks beacon. Slews 2 radians/sec.
e/ With initial 5 cavity Sperry Klystron cavities must be adjusted to get desired 500 mc bandwidth from 100 mc operating bandwidth. A new tube would give full 500 mc bandwidth.
f/ Normal command. Burst command: (360 gps x 4 pulses)/sec.
g/ To 3 db point.
h/ About 10 mils. (Acquisition data accuracy of 2 mils is input.)
i/ "Stacked Needle" Beams. Each of 3 trusses mounts 54 clusters of receiver horns, totalling 162 receiver beams.
j/ DDR beam width is varied with target range, from 5° at 300 n.mi. to 10° at 150 n.mi. and 20° at 75 n.mi.
k/ No radome. Integral truss and cellular structure hardened to 2.4 psi overpressure by coating having unity dielectric constant.
l/ R&D model of TTR will use Travelling Wave Tube in each channel (Az, El, Rn) with effective temp 700°K. Tactical Model will use MASER in 1.5° to 4.5°K environment to attain 150°K effective temp.
m/ Range resolution figure. Could be reduced to 10 yd if desirable.
n/ Later model DDR will have 60 megw peak power and 60 μsec pulsewidth which, with MASER-TWT, will attain 300 n.mi. range vs. 0.003 sq mi target.

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5. NIKE-ZEUS Missile.1/ A high performance multi-stage rocket using combined aerodynamic and reaction control in a Canard configuration is to be used as the NIKE-ZEUS anti-missile missile. A solid rocket booster provides thrust for 5 seconds and then separates at about 5.4 seconds after launch. A sustainer solid-propellant rocket stage then fires, and by providing about 36 g's of axial acceleration, increases missile velocity to 11,400 ft/sec at burnout within about 19 seconds after launch. Aerodynamic guidance is provided during sustainer action by the single guidance unit associated with the jet head. Upon separation of the sustainer or at any time it is required thereafter, the jet head is further maneuvered by the same autopilot and guidance unit to eliminate end game errors. A solid-propellant reaction motor providing 100 g seconds of impulse exhausts for 8 seconds through four swiveling nozzles embedded in the aerodynamic control surfaces to provide exoatmospheric control. A 20 g maneuver capability is maintained above 100,000 ft. altitude out to nearly 25 n.mi. and above 90,000 ft. altitude to beyond 50 n.mi. Times of flight and maneuver capabilities of the Wingless NIKE-ZEUS missile are shown in Figure 2, together with the 75-second time-of-flight curve for the Winged (R&D) NIKE-ZEUS missile it will replace. The thermonuclear warhead for the tactical NIKE-ZEUS will be the XW-50 weapon, [redacted] X-ray effects are considered a bonus,

1/ This missile is described in "Proposed Canard Control NIKE-ZEUS Missile," Report SM-35775 Douglas Aircraft Co., Inc., dated June 1959. Initial R&D flight tests beginning in 1959 will be performed with a missile of earlier design described in most prior studies. The new missile is intended to give increased range, shorter times of flight, greater simplicity, reliability and growth potential and is currently scheduled for flight testing in 1960. From a system point of view this increased performance is equivalent to doubling the power of the acquisition radar.

TIME OF FLIGHT CHARACTERISTICS NIKE-ZEUS

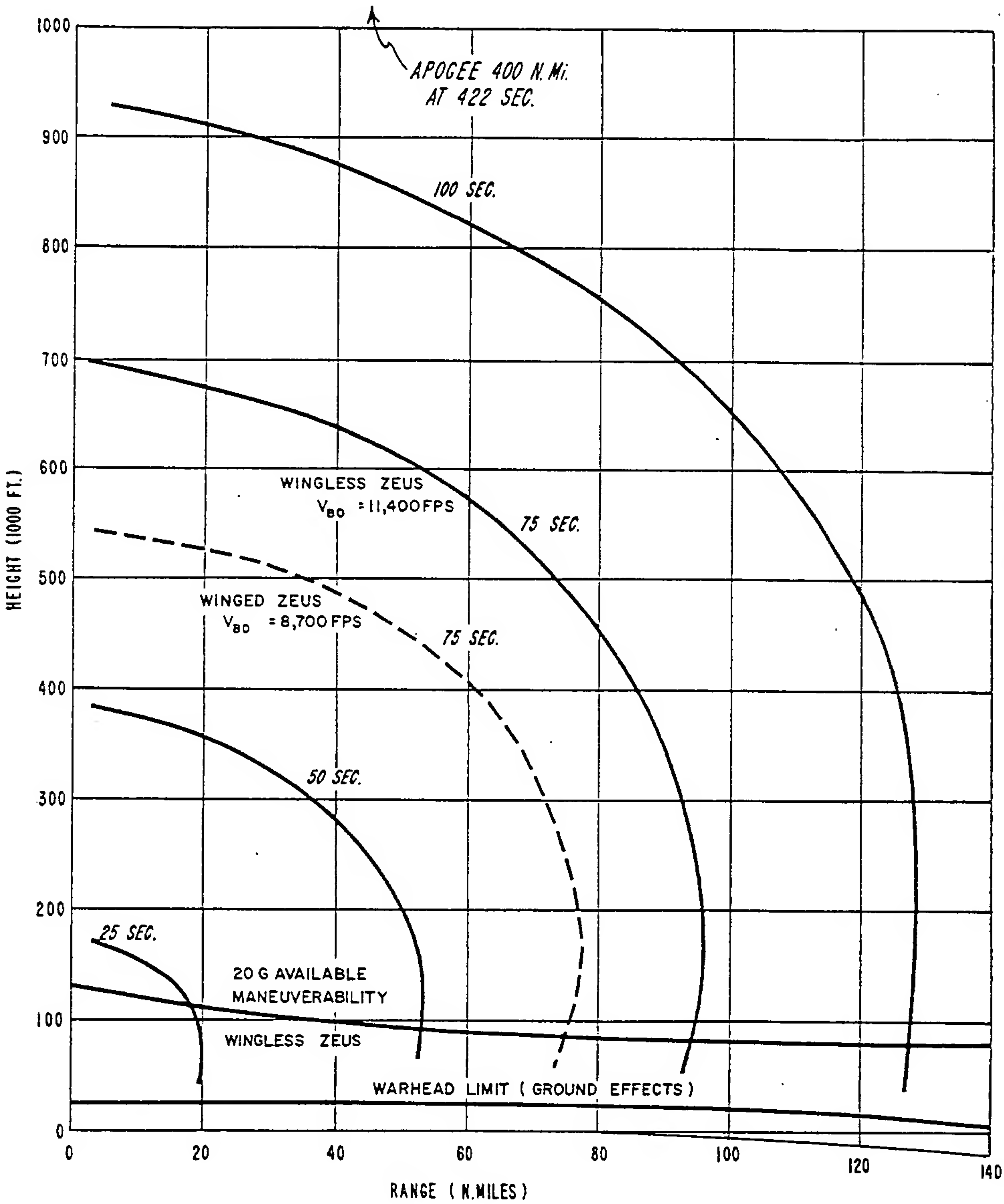

FIGURE 2
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FIGURE 2

TIME OF FLIGHT CHARACTERISTICS NIKE ZEUS

which may considerably extend the lethal radius. Some design characteristics of the Wingless NIKE-ZEUS missile are listed in Table II.

TABLE II

NIKE-ZEUS MISSILE CHARACTERISTICS

	Booster	Sustainer	Jethead	Over-all
Length	16' 11.5"			
Diameter	43.1"	36"		
Propellant Type	Polysulfide	Polysulfide	Polysulfide	
Burning Time (sec)	4.6	12	8	
Max. Velocity, Burnout, (feet per second)		11,400		11,400
Gross Weight, Takeoff (lb)	11,761			20,000
Gross Weight, Burnout (lb)				3,700

6. Decoy Discrimination. 2/ The NIKE-ZEUS system is designed to perform decoy discrimination at each battery. Information from the target tracking radar and an associated decoy discrimination radar constitute inputs to a decoy discrimination computer at the battery. The computer programs through each possibility for discrimination, performing most tests simultaneously. Outside of the atmosphere, discrimination could result from examination of signal amplitude, fluctuations in echo amplitude from the same target from pulse to pulse (any amplitude fluctuations due to scintillation or tumbling rate), or variations in echo as a function of transmitted frequency. Within the atmosphere

2/ For a discussion of decoy discrimination problems see Enclosure "D".

the degree of ionization, the spectrum analysis of re-entry radiation (including the infrared region), and aerodynamic slowdown are among the possible discrimination tests. The phenomena which will be utilized and the mechanization of the discrimination have not yet been specified pending further tests. However, the equipment to provide necessary inputs has been specified. Prior to discrimination, each target tracking radar will track the center of a "cloud" of undiscriminated targets, whether decoys or re-entry bodies. Coverage of the volume through which such a cloud passes would require a diameter of 25 n.mi. and extend from 50 to 250 n.mi. in range, exceeding the field of view of the target-tracking radar. The problem is solved in two steps. Additional wide-angle coverage is obtained from the decoy-discrimination radar slaved to the TTR tracking mount. The DDR has its own transmitter and receiver circuits and provides range and angle error signals to position the TTR. Each signal from the DDR is resolved in range within 40 yards (resolution to ten yards could be provided if desirable) and carried in a separate digital range gate. Second, the DDR beam width is varied from five degrees at 300 n.mi. to 20 degrees at 75-n.mi. range to maintain coverage of the 25-n.mi. diameter target array. Because of this broad beam, the decoy discrimination radar employs higher peak power, a longer pulse and lower frequencies than the target tracking radar to attain comparable range capabilities. The initial decoy discrimination computer utilizes approximately 100 tracking gates and can perform up to 100 separate discrimination tests simultaneously. This equipment is modular, and additional data processing equipment could be added to increase to any required capacity.

7. A possible sequence of decoy discrimination by the NIKE-ZEUS system is as follows: the TTR-DDR radars are locked onto a

target and decoy cloud based upon data received from the FAR and LAR. Individual tracking range units are distributed among those targets having larger signal amplitudes and all out-of-the-atmosphere discrimination techniques are applied to the radar responses. Unless complete discrimination has occurred, the TTR is now locked on a particle near the center of mass of this cloud. As re-entry occurs, the velocity histories of the particles are ascertained and compared. Those particles having very low ballistic coefficients are discriminated as light decoys, and from the ballistic coefficients and other characteristics of the remaining particles, the number of potential targets is considerably reduced. At this point, the TTR is slewed to the closest or earliest of these remaining targets, other TTR's are slewed to the other targets and missiles which have been previously launched are redirected, or additional missiles are launched to the individual remaining targets. Launch time is automatically selected with consideration to the resulting intercept altitude (ground effects), number of targets remaining, and required missile maneuver time. The salvo size to be fired against each target will be determined as a function of the operational reliability, the number of missiles remaining in the stockpile, and the number of targets remaining after discrimination. Consideration is being given to the use of a precursor burst at altitudes up to the maximum range of the missile 3/ as an aid to discrimination. One version of the presently planned warhead could produce [redacted] yield and up to [redacted] per cent of the energy released as X rays if desired for such purposes. Meteorites are removed as a discrimination problem in the R&D model by gating out all new targets in the 50 to 75-n.mi. altitude zone.

3/ 400 n.mi. is the maximum apogee of the Wingless NIKE-ZEUS missile.

8. Communications and Control. An extensive communications system is a vital portion of the NIKE-ZEUS system. The network requires long-wire lines, redundancy in switching and routing, high reliability, and great flexibility. Trunk lines to forward acquisition radars will be several hundred miles in length. Other elements of the system are interconnected by shorter lines. The data sent from an acquisition radar includes position and velocity coordinates, quality of data, time, and whether the data pertains to a single target or a "cloud." The message will require approximately 200 bits and the contractor estimates the total time required to send the 200-bit message (including coding, decoding, switching, transmission delay, and fault-checking) will, in 99 per cent of the cases, be lower than 0.4 seconds. 4/ The data system design is based on a bit transmission rate of 750 bits per second. In theory a message can go to any portion of the system from any other portion in the manner of direct-dialing long distance telephone communications. In practice, most of the messages will follow a more consistent routing. For example, the FAR must decide that a target exists, is hostile, and will be of interest to one or more addressees. The Ballistic Target Assigner at the LDC must operate on such messages from the FAR (or LAR) to assign targets to those batteries having the highest engagement capability for that target and which are not previously fully committed. The data from a LAR is the primary source for BTA operations. Target assignments are based primarily on predicted impact points and predicted times of intercept, with priority to those targets constituting the greatest threat from both considerations. Since track data is passed through all LDC's

4/ NIKE-ZEUS "Engineering Concept Review," ARGMA, 3-6 March 1959, page 236.

having batteries within range[5] to intercept the target, the assignment process may proceed simultaneously at more than one BTA. However, when an assignment to a battery is made, a claiming message is sent to other LDC's. Communications of target messages to the battery from the LDC (BTA) include tags of impact priority and the time parameter. Following each engagement, the battery reports results to the BTA which holds this information as part of its Hostile Targets Summary. Salvo sizes are determined at that time on the basis of the total remaining missile inventory for all batteries controlled by that LDC. Assignment of a hostile target to a battery, including coordination with other LDC's, is expected to be completed in less than one second. The LDC maintains displays for monitoring all target battery assignments, and monitoring personnel may view the progress of engagements from the standpoint of any defended point by pushing an appropriate button requesting a survey from that point. Weapon assignment is normally an automatic function, but a manual override is also provided. The individual firing batteries also have equipment and displays, termed the Battery Control and Monitoring Group, for monitoring individual engagements.

9. Self-Protection of the System. Design of NIKE-ZEUS structures and equipment has taken into consideration the necessity for protection of the system from nuclear-burst effects. All elements of the battery are being designed to withstand 5 psi overpressures. In the case of the TTR, this involves a radome of polyester glass pressurized at 5 psi. At the local defense

5/ Effective range of a NIKE-ZEUS battery at present is limited to about 75 n.mi. by system accuracy. The current BTL estimate of over-all accuracy, as briefed to WSEG at AOMC on 22 July 1959 is a $\delta_x \cong \delta_y \cong \delta_z \cong 150$ ft. This means that 99 per cent of the reliable missiles will miss by less than 550 feet at 75-n.mi. range. The new missile has adequate maneuverability and about 60 sec. time of flight to this range. The 550 ft. is a very conservative estimate of the lethal radius of the [redacted] warhead against a shielded hostile warhead, so this nominal battery range is, in this respect, also conservative.

level, the LDC building is being designed to withstand 10 psi. The LAR and FAR receiver hemispheres are the softest elements of the system (assuming adequate communications hardening). These are estimated by the contractor to withstand 2.4 psi from overhead burst and 3.3 psi from low angle of incidence. The 2.4 psi overpressure would result from the [redacted] NIKE-ZEUS warhead burst at 17,600-foot altitude or from a 10-MT hostile warhead burst at 60,300-foot altitude at the zenith of the radome. For these reasons and for considerations of safety to the population, NIKE-ZEUS planning considers 30,000 feet their minimum safe altitude for engagement. Moreover, the LAR/LDC is to be sited within the perimeter of the NIKE-ZEUS defenses with provision for input of remote LAR data to the LDC as required. All sensory elements of the NIKE-ZEUS system are protected by the system itself except for the FAR. Additional hardening of the FAR and LAR antennas to 5 psi is under consideration. The contractor considers this hardness attainable by increasing the density of the loaded-foam blocks constituting the antenna without changing their dielectric constant. Fire units (batteries) comprising any given local defense will be separated to reduce the likelihood of their simultaneous destruction.

RELATION OF NIKE-ZEUS TO ICBM DEFENSE

10. Currently Available Systems. By decision of the Secretary of Defense,[6/] the Army was assigned responsibility for "research and development work on local acquisition and target tracking radars" and the "defense missile for the active portion of the ICBM defense system." This has resulted in the NIKE-ZEUS

6/ Memorandum for the Secretary of the Army and the Secretary of the Air Force, "Anti-ICBM Program," Office of Secretary of Defense, 25 April 1957.

development to date. The same decision directed that the Air Force develop the "advanced acquisition radars required for the active defense system" and development of the "early warning system." Thus the Air Force has developed and is currently installing the BMEWS system for early warning. No other active anti-ICBM or anti-IRBM defense system is currently available or in development.

11. Defense in Depth. The BMEWS system which provides desirable early warning to NIKE-ZEUS, as it does to other elements of the defense and retaliatory forces, is at present the only forward extension of the ballistic missile defense system. Other concepts, such as MIDAS and active systems for engagement of ICBM's during the propulsion and mid-course trajectory have been proposed. The NIKE-ZEUS, which is essentially a terminal system, would be compatible with other systems which operate earlier in the ballistic missile trajectory. Based upon current thinking in air defense, it would appear desirable to have defense in depth against ballistic missiles (i.e., extending the duration of the battle in both time and space). In this concept, NIKE-ZEUS would be the "clean-up" system required to engage those targets which evade the longer range or earlier engagement systems. The U.S. Air Force has study contracts for consideration of such anti-ICBM systems.[7]

12. Growth Potential. Experience with earlier NIKE systems indicates that improved performance of many components of the NIKE-ZEUS system should be expected with the passage of time. For example, the decoy discrimination radar which would initially

7/ For example, Convair "Systems Study in Defense Against Ballistic Missiles," Tech. Report AO-37-59, 1 December 1958-31 May 1959.

employ a 20-megawatt, 20-microsecond pulse transmitter giving +6 db signal-to-noise ratio against a 0.1-square meter target at a range better than 600 miles, should improve to 60 megawatts and 60 microseconds giving the same performance against a target having a cross section of only 0.01-square meter. The introduction of MASERS is already contemplated in the receiver systems of the target tracking radars for greatly improved performance. Peak power of the acquisition radars is expected to increase from 5 megawatts to 20 megawatts, and higher acquisition radar frequencies may be sought to eliminate blackout effects and beam bending due to nuclear bursts. The wingless configuration of the NIKE-ZEUS missile already represents a growth from the original winged design, but it has a specific impulse (I_{sp}) of just over 220 seconds. There is no reason to believe that an even higher performance missile with higher specific impulse fuels could not ultimately be developed if required, as the state of the missile art and needs of the system progress. The greatest immediate requirement for growth is probably in the field of decoy discrimination. All of our studies have shown that traffic handling capacity, set largely by the number of TTR's in each battery, is a critical problem. Successful development of an appropriate electronically phased array antenna to replace the TTR's plus an increase of computer capacity could quite appreciably enhance the traffic capacity.

13. Application to Other Targets. The NIKE-ZEUS system is designed primarily to counter ICBM and IRBM targets. The Wingless NIKE-ZEUS missile has maximum ordinates up to 400 n.mi. and the guidance system is readily adaptable to use as an anti-satellite system. For such an application, it probably would be desirable to add an additional propulsion stage. In the opinion of the missile designers, the change from a single-phase to a two-phase

APPENDIX "A" TO ENCLOSURE "A"

ESTIMATED NIKE-ZEUS PROGRAM COST

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jet head control engine would be the only major change to the basic missile required to attain a substantial anti-satellite capability. No substantial research and development effort is currently going into the anti-airborne aspects of NIKE-ZEUS, as a result of an Army decision to concentrate available R&D funds on the anti-missile missile system. However, such an anti-aircraft application could be developed. The NIKE-ZEUS system, preferably with acquisition capabilities[8/] extended to cover lower altitudes of approach, could answer much of the threat from boost-glide, air-launched ballistic missiles and other air-to-surface missiles. Because of the capability of the computers to back-track the trajectory, the system may also prove to be of some value in anti-submarine warfare by quickly locating those submarines which have launched ballistic missiles. Its usefulness will depend upon the accuracy of location, which has not been analyzed in this paper. Because no other active anti-ICBM system has reached its state of development, the NIKE-ZEUS effort has been directed primarily toward meeting the ballistic missile threat.

OPERATIONAL CONSIDERATIONS

14. Alert Requirements and System Maintenance. The NIKE-ZEUS system is being designed for continuous operation. Those elements (such as the missiles) which are not so operated are available with less than 30 seconds warning. Most elements of the system, such as acquisition radars and computers, displays and communications in particular are in the continuous operation category. Three shielded caps which rotate with the acquisition radar receiving antenna are to permit maintenance to be performed while that radar is in operation and the antenna is rotating. Trouble

8/ Acquisition data accurate to within one beam width (12 mils) is required for designation to, and acquisition by, the NIKE-ZEUS TTR. In the hemispherical LAR designs the uncertainty in elevation is 4 mils at 3° and 12 mils at 0.5° elevation as a practical limit on target acquisition. These low angles are not expected to occur in the ballistic missile cases.

alarms and maintenance consoles are to be provided for all operating equipments. Self-checking programs and fault-locating indicators characterize the entire system, which should operate more like a commercial television station and telephone network than like the more familiar military radars and military radios. The TTR/DDR and MTR are all to be completely automatic and self-checking. They can continuously exercise and check themselves at all times when not in actual engagement. Shut-down of a TTR will inevitably reduce traffic capacity proportionally (i.e., by one-third in a nominal battery). Redundancy of computers and MTR's, and provision for input to an LDC of all required LAR data from a remote source instead of the associated LAR, will give the individual defenses and batteries a capability for continuous operation in the event an individual radar must be down briefly for mechanical repair. Such down-time would usually be scheduled on a defense-wide basis to minimize the reduction in defense potential. NIKE-ZEUS missiles require a minimum of 15 seconds of warning prior to lift-off. Of this total, 13 seconds is required prior to a "fire" signal. Run-up time for the gyroscopes and filament power for the transmitter are the 13-second limiting elements in alerting the launching area. One second is then required from MTR designation to acceptance of a missile. A further one-second delay is necessary after the "fire" signal has been given to ignite the hydraulic power supply, uncage the gyro, activate the battery and ignite the booster squibs for lift-off. In summary, NIKE-ZEUS requires no external warning but would be more effective if such external warning is available.

15. Early Warning from FAR on ICBM's. In the event that BMEWS for any reason fails to provide early warning of approaching ICBM's, the FAR's should augment warning of the NIKE-ZEUS batteries by as much as 100 seconds or more (for the lower re-entry angles)

beyond LAR coverage. The amount of such additional warning is greatly dependent upon re-entry angle of the ICBM trajectory, radar cross section of the target, and geographical deployment of the FAR's relative to the LAR and batteries. Such warning can be transmitted to other elements of the NORAD system through communications planned to pass such information to and from NIKE-ZEUS units. In such a case 4 to 7 minutes of warning might be available to "backstop" BMEWS. The purposes of the FAR radars from the NIKE-ZEUS point of view are that they increase knowledge of the type and spacing of the attack, provide side as well as frontal aspects of targets (which will assist in detecting re-entry bodies designed to appear small head-on), and perhaps to assist in decoy discrimination. FAR's also will greatly complicate an enemy's jamming problem because of their frequency and geographical spread from the LAR's, and may circumvent blackout effects on the LAR's because of the different target aspects afforded. LAR's alone would provide only 150 seconds of warning against ICBM's.

16. Personnel Requirements. So much of the NIKE-ZEUS equipment is automatic that engagements could be performed with very minimal crews. However, the continuous maintenance of equipment, the simultaneous monitorship of all displays within seconds after alerting, and ready availability of human decisions for possible overriding of the equipment are deemed important by the system designers. Hence, the tentative military manning strengths for the purpose of cost analysis have envisioned three shift operations (plus usual allowances for leave, administrative supervision, and logistic support). Nominal totals of 100 military personnel each per FAR, LAR/LDC, and Battery are the only estimates currently available. Additional civilian contractor maintenance personnel will be required, possibly beginning with numbers equal to the military upon activation, but possibly phasing downward at later dates.

The bulk of the military and civilian personnel required must be highly trained personnel of well-above-average intelligence.

17. <u>Meeting the Sea-Launched Ballistic Missile Threat</u>. The reduced accuracy of the LAR at very low elevation angles could be a limiting factor in engagement of sea-launched missiles. However, by reference to the POLARIS ballistic trajectories 9/ it is evident that more than six minutes of warning should be available from the LAR on the shortest range trajectory [redacted] these are not easily obtained without a penalty in accuracy. The re-entry velocities and maximum decelerations for short range are much lower than for ICBM's [redacted]

The FAR's would not contribute materially to NIKE-ZEUS coverage of SLBM trajectories because of their geographical locations to the north, but the nature of the other elements (LAR/LDC's and Batteries, including TTR/DDR's and MTR's) should permit engagement of sea-launched missiles with at least as much effectiveness as ICBM's of comparable radar cross sections. In fact, the lower velocities would more than offset factors of two to five in radar cross sections, which might exist between ICBM's and SLBM's, and would result in higher engagement capacity against the SLBM's.

9/ "The Fleet Ballistic Missile Program, POLARIS FY 1959-1960, Revised 10 March 1959," Navy Ballistic Missiles Committee, page 70.

NIKE-ZEUS SYSTEM COSTS

18. Total Program Costs. Through the first full year of complete operational deployment for a 60-battery program (9 FAR, 25 LAR-LDC, 60 batteries, and 3,612 anti-missile missiles) total program costs have been estimated for WSEG by the Army at approximately $9.2 billion. Corresponding total program costs for a 120-battery program (9 FAR, 35 LAR-LDC, 120 batteries, and 6,612 AMM) are estimated by the Army at about $14.6 billion. These costs are based upon providing an initial operating capability in September 1963 and making the last unit operational in FY 66 and FY 69, respectively. Details are presented in Appendix "A" to this Enclosure.

19. Breakdown of Program Costs. Included in the total program costs are $1.5 billion for RDT&E (Research and Development Tests and Evaluation) for the 60-battery program and $1.6 billion for RDT&E in the case of the 120-battery program. Total investment costs are estimated at $7.012 billion and $11.54 billion respectively for the two programs. Total operating costs from FY 1964 through the end of FY 69, the first full year of complete operational deployment, would amount to $0.6 billion for the 60-battery program and $1.4 billion for the 120-battery program. Thereafter program annual operating costs, which we consider low by a factor of two (for the reason stated above and amplified in paragraphs 11 through 13 of Appendix "A" to this Enclosure) are estimated by the Army at $330 million for the 60-battery program and $571 for the 120-battery program.

20. Types of Expenditure. An analysis by WSEG of the Army cost data shows that approximately half of the total program costs for NIKE-ZEUS are represented by the procurement of unique support equipment and spares (other than missiles and spares). These data are contained in Table II, Appendix "A" to this Enclosure.

21. Unit System Costs. The breakout of investment and annual operating costs for the individual FAR, LAR and LDC, and individual NIKE-ZEUS battery are detailed in Table III of Appendix "A" of this Enclosure. The per-unit investment costs in millions are $72 per FAR, $62.25 per LAR and LDC, and $72.61 per battery for the 120-battery program. Per unit costs are slightly higher, as might be expected, for the smaller 60-battery program. Annual operating costs were estimated by the Army at between $3.1 million and $3.7 million for each of these elements (single FAR, LAR-LDC, or battery) in both programs. However, these annual operating cost estimates, for lack of data, had to omit several large costs. As a result, WSEG estimates they are low by a factor of two or more.

22. Total Investment Costs and Total Operating Costs. The total investment costs have been estimated at $7.012 billion for the 60-battery program and at $11.54 billion for the 120-battery program. Thus the battery-slice investment cost (total divided by 120) in the larger program is just over $96 million. The total annual operating costs, which we consider low by a factor of two (for the reason stated above and amplified in paragraphs 11 through 13 of Appendix "A" to this Enclosure) have been estimated at $330.1 million for the 60-battery program and $571.1 million for the 120-battery program. These annual operating costs are effective when the force level is fully operational.

APPENDIX "A" TO ENCLOSURE "A"

ESTIMATED NIKE-ZEUS PROGRAM COST

APPENDIX "A" TO ENCLOSURE "A"

ESTIMATED NIKE-ZEUS PROGRAM COST

PURPOSE

1. To illustrate the approximate cost of a NIKE-ZEUS anti-missile missile program.

SCOPE

2. Cost estimates will cover two programs:

a. 9 Forward Acquisition Radar (FAR) units; 25 Local Defense Centers (LDC) and Local Acquisition Radars (LAR); 60 Batteries; 3,000 tactical anti-missile missiles (AMM) and 612 non-tactical missiles.

b. 9 FAR; 35 LDC/LAR; 120 batteries; 6,000 tactical AMM's and 612 non-tactical missiles.

3. Estimated total program costs are shown in terms of obligations through the first full year of complete system operational deployment. Also shown is the average cost of a battery, local defense center, and forward acquisition radar detachment within each program.

SOURCE

4. Cost estimates furnished WSEG by the Army Staff are shown in Exhibits A through E.

SUMMARY

5. Table I summarizes the yearly obligations required for both programs in terms of conventional (complete round fundings), and lead-time funding. Conventional funding usually requires the obligation of all money for a given quantity of end items within the fiscal year authority is granted to obligate. This funding method does not preclude the obligation of funds for long lead-time components of end items. It does require that all funds for all components of a stated quantity of end items be obligated at one time.

TABLE I

TOTAL PROGRAM COST (Obligations)
(Millions of Dollars Through First Full Year of Complete Operational Deployment)

Program cost includes all RDTE, Construction, procurement of unique equipment and missiles, and maintenance and operation.

Cumulative Force Level	60-Battery Program		
	IOC - September 1963		
		Total $ By Type of Funding	
FAR-LDC-Btry	Fiscal Year	Conventional	Lead-Time
--	59 and Prior Yrs	285.40	285.40
--	60	437.00	437.00
--	61	2284.20	1519.18
--	62	3024.21	2339.49
--	63	1940.34	2448.53
4- 7-12	64	421.68	1086.12
8-21-35	65	300.61	544.63
9-25-60	66	269.59	302.61
9-25-60	67	240.82	240.89
9-25-60	TOTAL	9203.85	9203.85

	120-Battery Program		
	IOC - September 1963		
--	59 and Prior Yrs	285.40	285.40
--	60	437.00	437.00
--	61	2284.20	1519.18
--	62	3024.21	2339.49
--	63	2678.42	2814.04
4- 7-12	64	2177.77	2292.15
8-21-35	65	2039.63	2178.21
9-35-63	66	565.61	1361.95
9-35-91	67	377.49	602.60
9-35-118	68	361.22	400.93
9-35-120	69	340.24	340.24
9-35-120	TOTAL	14,571.19	14,571.19

6. The other method of funding does not require the obligation of all funds for a given quantity of end items within one year from authority to obligate. Instead, the total obligation is spread over a number of years to cover, first, the ordering of long lead-time components of an end item and, finally, the ordering of very short lead-time components. For the two methods, the total amount expended (checks issued) in any year and the total cost of the whole program will not vary substantially because of the funding method.

7. By program, Table II summarizes the Army's estimate of the ZEUS system cost by major type of expenditure through the first year of total unit deployment. The costs shown here are those illustrated in Table I.

8. Details on conventional and lead-time funding on the 60 and 120 battery programs, as furnished WSEG by the Army, are to be found in Exhibits "A" - "D", pages 34 to 37.

9. Table III shows an approximate average cost for each type of unit within each of the designated programs after the entire system becomes fully operational. The investment costs, with the exclusion of R&D, are those incurred during the development and deployment years covered in Tables I and II. The annual operating costs represent the estimated requirements to maintain the system in the years following the cut-off date in Tables I and II. A detailed breakdown of the investment and annual operating costs for each system unit may be found in Exhibit "E", page 38.

GENERAL COMMENTS

10. The Army believes the data submitted to WSEG includes the major costs associated with the NIKE-ZEUS system. However, at this stage of system development there are a number of elements

TABLE II

APPROXIMATE TOTAL COST OF PROGRAM
BY MAJOR TYPE OF EXPENDITURE
(Millions of Dollars)
(Through First Year of Full System Deployment)

COST ITEM	PROGRAM	
	60-Battery	120-Battery
Investment		
RDTE and Support Construction	1492.34	1566.74
Unique Support Equipment, Spares	4180.05	6663.80
Missiles, Spares	1425.00	2354.00
Base Construction	1406.70	2512.60
TOTAL	8504.09	13,107.14
Program Operating Costs		
Facility maintenance; missile, unique equipment maintenance; operation of communications	623.74	1431.77
GRAND TOTAL	$ 9127.83	$ 14,538.91

NOTE: Total cost varies slightly from that shown in Table I because inputs for missiles and unique support equipment represent a total of a series of averages for each type of unit in the program. For the composition of each program, see paragraph 2.

for which accurate cost data do not exist. These omissions are outlined in paragraph 19 of this paper. The major omissions are in the field of tactical unit and depot maintenance training, construction of the communication network, personnel pay, and depot level maintenance. It is anticipated that in the near future the Army will be able to furnish more complete cost data covering the major omissions.

11. It is possible the annual operating costs may be in practice at least double those shown in Table III. For example, ZEUS annual operating costs shown represent about 5 per cent of the investment cost, whereas for other missile systems (TITAN, MINUTEMAN, AJAX, HERCULES) annual costs vary from about 10 to 17 per cent of their respective investment cost.

12. Another indication that the annual operating costs are lower than they will be in practice is the amount shown for replacement parts for missiles and unique equipment. Cost estimates for other solid propellant missile systems (MINUTEMAN, POLARIS) have shown that the total annual cost for all maintenance, repairs, and replacement for missiles runs at least 20 per cent of the missile investment cost. This item, as part of the annual costs shown in Table III, only amounts to about .5 per cent of the investment in missiles. MINUTEMAN and POLARIS cost estimates have also shown that total annual cost for maintenance and replacement of unique support equipment will run at least 10 per cent of the investment cost. In the annual operating costs shown for all system units in Table III, this item only represents about 3 per cent of the investment in unique equipment.

13. If the percentage factors used in MINUTEMAN and POLARIS were applied to the ZEUS annual costs shown in Table III (and the back-up data in Exhibit E), the annual operating cost for a ZEUS

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TABLE III

NIKE-ZEUS UNIT SYSTEM COST WHEN FORCE LEVEL FULLY OPERATIONAL
(Millions of Dollars)
(R&D Excluded)

Unit	No. Units (Force Level)	COST: Per Unit Invest	Per Unit Annual Oper	All Units Invest	All Units Annual Oper
60-Battery Program					
FAR	9	72.00	3.4	648	30.6
LDC/LAR	25	65.32	3.1	1633	77.5
Btry	60	78.84	3.7	4731	222.0
TOTAL		xxxx	xxx	7012	330.1
120-Battery Program					
FAR	9	72.00	3.4	648	30.6
LDC/LAR	35	62.25	3.1	2179	108.5
Btry	120	72.61	3.6	8713	432.0
TOTAL		xxxx	xxx	11.540	571.1

NOTES:
a. The annual operating costs represent an estimated amount to support the system during the years following the cut-off date in Tables I and II. The investment costs are incurred during the years covered in Tables I and II. As an investment item, R&D is excluded because data are not available for prorating this cost to different types of system units. Total R&D for all units of each program is shown in Table II.
b. See Exhibit "E" for System Cost Details.
c. It should be noted that the investment costs substantially reflect the major initial system cost; however, the annual costs may, in practice, at least double those shown, See paragraphs 11-14.

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battery would be over $11 million, and over $7 million for an LDC and a FAR unit. It appears reasonable to tentatively conclude, until more complete cost estimates can be developed, that annual costs for the FAR's and LDC's will at least double those shown in Table III, and in the case of the batteries, this would be a very conservative estimate.

14. Although the investment costs shown in Table III will be higher when more complete estimates are developed, we believe most of the major items are included and that future estimates will not substantially change those given in this paper.

ASSUMPTIONS

15. For either program the Initial Operational Capability (IOC) objective is September, 1963. The IOC represents 1 FAR, 1 LDC, and 3 batteries each with 50 missiles and launchers operational on site. For the 60-battery program, the objective is to have all units operational within FY 1966, and in the case of the 120-battery program, within FY 1969. To meet either of these objectives a quarterly production rate of unique equipment for 1 FAR, 4 LDC, 7 batteries, and 425 missiles has been assumed.

16. The typical NIKE-ZEUS battery is composed of 3 Target Tracking Radar; 3 Decoy Discrimination Radar; 10 Missile Tracking Radar; 50 Anti-Missile Missiles and 50 launchers.

17. Training and depot maintenance buildings will be inherited from other programs.

18. All land for tactical base sites must be purchased by the government.

QUALIFICATIONS

19. For the total program cost in Tables I and II, and the average cost per unit of the ZEUS System in Table III, the cost elements not represented are:

Investment Items Excluded

a. Cost of nuclear warheads.[1]

b. System capabilities other than ballistic missile defense. For example, possible anti-satellite capability.

c. Nuclear power sources which may be found desirable at remote FAR sites.

d. Chemical, bacteriological protection, if required.

e. Hardening of base sites for blast and/or fallout, if required.

f. Production of training and depot maintenance equipment.

g. Construction of off-site communication network.

h. Production of standard (non-unique) organizational equipment for the ZEUS units, i.e., vehicles, etc. It is possible that enough standard equipment exists for allocation to ZEUS units without the necessity of additional initial purchases.

Annual Operating Items Excluded

i. Personnel costs are not included in the program obligations in Tables I and II because the organization of the ZEUS units has not been established; however, 100 men per unit is an approximate figure and 3780 dollars/man/year is the Army average per capita CONUS pay and allowance cost based on FY 60 budget. Using these data, personnel costs were estimated and included in the average unit cost (part of annual operating - Table III).

1/ For warhead costs see Estimated Costs of CONUS Air Defense, WSEG, 22 June 1959, TOP ~~SECRET-RD~~.

j. Training of replacement personnel is excluded in all tables. It is anticipated that training requirements, both of an investment and annual nature, will be available in the near future when a training program will be more fully developed by the Army staff.

k. In all tables annual replacement and maintenance of standard organizational equipment -- probably a minor item -- is not included. Also excluded is cost of replacing depot maintenance equipment.

20. The chief cost elements included and which should represent the major cost of the system are:

Investment Items Included

a. For Program Obligations in Tables I and II, all RDT&E and all construction required for R&D facilities. Also procurement in support of R&D is included.

b. In Tables I, II, and III, procurement of the specified number of tactical and non-tactical missiles. It is assumed that during the development and deployment years covered in Tables I and II, all the non-tactical missiles were used for proof firings, engineer-user tests, and annual battery training firings. In Table III, an annual expenditure of one non-tactical missile per battery for practice firings is included in annual operating costs.

c. In Tables I, II, and III, procurement of all unique support equipment with spares.

d. Base construction in Tables I, II, and III, including maintenance facilities for local (organizational) maintenance. Base construction includes land acquisition, site preparation and facilities, troop housing, and family housing.

Annual Operating Items Included

e. Personnel costs, excluded in the total program cost in Tables I and II, were estimated and included in the average cost for a system unit in Table III.

f. Operation and maintenance costs for base facilities. Included in all tables are follow-on spares for maintenance of missiles and unique support equipment, rental of off-site communications, and general maintenance costs for base facilities which may run about 5 per cent of the base investment cost.

21. Although the total program cost through our selected cut-off date is chiefly sensitive only to the size of the program, the amount required for obligation in any particular year is only valid within the context of the stated assumptions regarding IOC, quarterly production rate, method of funding and, of course, size of the program.

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EXHIBIT "A"

NIKE-ZEUS

9 FAR's 25 LDC's 60 BATTERIES 3,612 MISSILES

INITIAL OPERATIONAL CAPABILITY (IOC) SEPT 63

PROGRAM FUND REQUIREMENTS
(In Millions of Dollars)

Conventional, Complete Round Funding

FISCAL YEAR	DEVELOPMENT			OPERATIONAL				TOTAL
	RDT&E[a]	MCA	TOTAL	PEMA	MCA	O&MA	TOTAL	
59 & Prior	235.65	25.29	260.94	24.46	.00	.00	24.46	285.40
60	239.00	61.00	300.00	137.00	.00	.00	137.00	437.00
61	324.50	15.00	339.50	1570.30	374.40	.00	1944.70	2284.20
62	218.00	7.40	225.40	2256.41	539.90	2.50	2798.81	3024.21
63	126.00	3.50	129.50	1341.40	459.60	9.84	1810.84	1940.34
64	89.00	3.50	92.50	193.28	32.80	103.10	329.18	421.68
65	55.00	2.50	57.50	89.70	.00	153.41	243.11	300.61
66	47.00	1.50	48.50	48.18	.00	172.91	221.09	269.59
67	37.00	1.50	38.50	20.34	.00	181.98	202.32	240.82
TOTAL	1371.15	121.19	1492.34	5681.07	1406.70	623.74	7711.51	9203.85

NOTE: Last Major Item Operational 4th Quarter, Fiscal Year 1966

a/ These figures do not include cost of providing SAGE with ZEUS data on air supported targets or providing within the NIKE-ZEUS system an air defense capability against air supported targets.

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EXHIBIT "B"

NIKE-ZEUS

9 FAR's 25 LDC's 60 BATTERIES 3,612 MISSILES

INITIAL OPERATIONAL CAPABILITY (IOC) SEPT 63

PROGRAM FUND REQUIREMENTS
(In Millions of Dollars)

Lead-time Funding

FISCAL YEAR	DEVELOPMENT			OPERATIONAL				TOTAL
	RDT&E a/	MCA	TOTAL	PEMA	MCA	O&MA	TOTAL	
59 & Prior	235.65 b/	25.29	260.94	24.46	.00	.00	24.46	285.40
60	239.00	61.00	300.00	137.00	.00	.00	137.00	437.00
61	324.50	15.00	339.50	805.28	374.40	.00	1179.68	1519.18
62	218.00	7.40	225.40	1571.69	539.90	2.50	2114.09	2339.49
63	126.00	3.50	129.50	1849.59	459.60	9.84	2319.03	2448.53
64	89.00	3.50	92.50	857.72	32.80	103.10	993.62	1086.12
65	55.00	2.50	57.50	333.72	.00	153.41	487.13	544.63
66	47.00	1.50	48.50	81.20	.00	172.91	254.11	302.61
67	37.00	1.50	38.50	20.41	.00	181.98	202.39	240.89
TOTAL	1371.15	121.19	1492.34	5681.07	1406.70	623.74	7711.51	9203.85

NOTE: Last Major Item Operational 4th Quarter, Fiscal Year 1966

a/ These figures do not include cost of providing SAGE with ZEUS data on air supported targets or providing within the NIKE-ZEUS system an air defense capability against air supported targets.
b/ Some funds not related to ZEUS Program.

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EXHIBIT "C"

NIKE-ZEUS

9 FAR's 35 LDC's 120 BATTERIES 6,612 MISSILES

INITIAL OPERATIONAL CAPABILITY (IOC) SEPT 63

PROGRAM FUND REQUIREMENTS
(In Millions of Dollars)

Conventional, Complete Round Funding

FISCAL YEAR	DEVELOPMENT			OPERATIONAL				TOTAL
	RDT&E[a]	MCA	TOTAL	PEMA	MCA	O&MA	TOTAL	
59 & Prior	235.65	25.29	260.94	24.46	.00	.00	24.46	285.40
60	239.00	61.00	300.00	137.00	.00	.00	137.00	437.00
61	324.50	15.00	339.50	1570.30	374.40	.00	1944.70	2284.20
62	218.00	7.40	225.40	2256.41	539.90	2.50	2798.81	3024.21
63	126.00	3.50	129.50	1976.67	562.40	9.85	2548.92	2678.42
64	89.00	3.50	92.50	1506.68	473.20	105.39	2085.27	2177.77
65	55.00	2.50	57.50	1324.29	459.60	198.24	1982.13	2039.63
66	47.00	1.50	48.50	161.97	103.10	252.04	517.11	565.61
67	37.00	1.50	38.50	55.56	.00	283.43	338.99	377.49
68	36.40	1.50	37.90	33.16	.00	290.16	323.32	361.22
69	35.00	1.50	36.50	13.58	.00	290.16	303.74	340.24
TOTAL	1442.55	124.19	1566.74	9060.08	2512.60	1431.77	13004.45	14,571.19

NOTE: Last Item Operational 1st Quarter, Fiscal Year 1969

a/ These figures do not include cost of providing SAGE with ZEUS data on air supported targets or providing within NIKE-ZEUS system an air defense capability against air supported targets.

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Exhibit "C" to
Appendix "A" to
Enclosure "A"
WSEG Report No. 45

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EXHIBIT "D"

NIKE-ZEUS

9 FAR's | 35 LDC's | 120 BATTERIES | 6,612 MISSILES

INITIAL OPERATIONAL CAPABILITY (IOC) SEPT 63

PROGRAM FUND REQUIREMENTS
(In Millions of Dollars)

Lead-time Funding

FISCAL YEAR	DEVELOPMENT			OPERATIONAL				TOTAL
	RDT&E a/	MCA	TOTAL	PEMA	MCA	O&MA	TOTAL	
59 & Prior	235.65	25.29	260.94	24.46	.00	.00	24.46	285.40
60	239.00	61.00	300.00	137.00	.00	.00	137.00	437.00
61	324.50	15.00	339.50	805.28	374.40	.00	1179.68	1519.18
62	218.00	7.40	225.40	1571.69	539.90	2.50	2114.09	2339.49
63	126.00	3.50	129.50	2112.29	562.40	9.85	2684.54	2814.04
64	89.00	3.50	92.50	1621.06	473.20	105.39	2199.65	2292.15
65	55.00	2.50	57.50	1462.87	459.60	198.24	2120.71	2178.21
66	47.00	1.50	48.50	958.31	103.10	252.04	1313.45	1361.95
67	37.00	1.50	38.50	280.67	.00	283.43	564.10	602.60
68	36.40	1.50	37.90	72.87	.00	290.16	363.03	400.93
69	35.00	1.50	36.50	13.58	.00	290.16	303.74	340.24
TOTAL	1442.55	124.19	1566.74	9060.08	2512.60	1431.77	13,004.45	14,571.19

NOTE: Last Major Item Operational 1st Quarter, Fiscal Year 1969

a/ These figures do not include cost of providing SAGE with ZEUS data on air supported targets or providing within the NIKE-ZEUS system an air defense capability against air supported targets.

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EXHIBIT "E"

ESTIMATED AVERAGE SYSTEM COST FOR 60- AND 120-BATTERY PROGRAM

COST ITEM	COST PER UNIT					
	60-Btry Program			120-Btry Program		
	Btry	LDC	FAR	Btry	LDC	FAR
Investment						
50 Missiles, Initial Spares	23.75	-	-	19.70	-	-
Unique Equip., Initial Spares	38.53	55.20	54.25	36.27	52.09	54.25
Base Construction	16.56	10.12	17.75	16.64	10.16	17.75
Land Acquisition	(.30)	(.04)	(.09)	(.30)	(.04)	(.09)
Site Preparation	(.45)	(.11)	(.17)	(.45)	(.11)	(.17)
Troop Housing	(15.40)	(9.55)	(16.92)	(15.47)	(9.59)	(16.92)
Family Housing	(.41)	(.42)	(.57)	(.42)	(.42)	(.57)
Standard Org. Equipment	UK	UK	UK	UK	UK	UK
Initial Training and Equip.	UK	UK	UK	UK	UK	UK
Depot Maintenance Equipment	UK	UK	UK	UK	UK	UK
Communication Network	UK	UK	UK	UK	UK	UK
TOTAL	78.84	65.32	72.00	72.61	62.25	72.00
Annual Operating						
Personnel Pay, Allowance	.378	.378	.378	.378	.378	.378
Missile Replacement Parts	.120	-	-	.100	-	-
Unique Equip. Replacement Parts	.890	1.210	1.090	.860	1.180	1.090
Base Operation and Maintenance	.828	.506	.888	.832	.508	.888
Rental of Communications	1.036	1.036	1.036	1.060	1.060	1.060
Depot Maintenance	UK	UK	UK	UK	UK	UK
Replacement Training	UK	UK	UK	UK	UK	UK
Training Firings[a/]	.475	-	-	.394	-	-
TOTAL	3.727	3.130	3.392	3.624	3.126	3.416

a/ Number per year not known. There is a possibility that no annual training firings will be required. Cost shown for one non-tactical missile may over-state probable actual cost by significant amount.

NOTES:
1. Battery composition is 3 TTR, 3 DDR, 10 MTR, 50 launchers with 50 anti-missile missiles.
2. For both programs, unique support equipment production rate to equip 7 batteries, 4 LDC and 1 FAR per quarter; missile production rate at 425 per quarter.
3. For the 60-btry program, total missile production assumed is 3,000 tactical missiles and 612 non-tactical for proof firings, engineer-user tests, and annual practice firings through the cut-off date in Tables I and II. For the 120-battery program, total missile production assumed is 6,000 tactical and 612 non-tactical.

4. Average missile unit cost for the quantity produced, without warhead, is 475,000 dollars for the 60-battery program and 394,000 dollars for the 120-battery program. Except for warhead, missile unit cost includes all costs associated with the purchase of the complete unit including adaption kits, initial spares, and transportation.

5. Initial spares represent about 15 per cent of the unit cost for missiles and unique euipment.

6. Per site base construction assumes 246 acres for a battery, 37 acres for a LDC, and 35 acres for a FAR site at $1,000 per acre. Construction covers all costs, except possible hardening, and includes bases for 2 batteries, 1 LDC, and 5 FAR sites [redacted] for the 60-battery program and 6 batteries, 2 LDC, and 5 FAR sites [redacted] for the 120-battery program.

7. Personnel pay and allowances have been calculated on the basis of 100 men per unit at $3,780 per man year.

8. Annual base operation, maintenance calculated on basis of 5 per cent of investment value of the base.

9. Annual rental of communications is a very approximate guess because site location has not been established. Signal Corps believes about $174 million per year for the 120-battery program and $97.4 million per year for the 60-battery program is the present best estimate. Total annual cost has been prorated evenly for all units of the system.

10. Replacement parts for missiles and unique equipment (follow-on spares), as part of total annual maintenance cost, are as calculated by the Army staff.

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ENCLOSURE "B"

THE POTENTIAL VALUE OF THE NIKE-ZEUS SYSTEM
IN DEFENSE OF POPULATION AND POPULATION CENTERS

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ENCLOSURE "B"

THE POTENTIAL VALUE OF THE NIKE-ZEUS SYSTEM IN DEFENSE OF POPULATION AND POPULATION CENTERS

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FIGURES

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ENCLOSURE "B"

THE POTENTIAL VALUE OF THE NIKE-ZEUS SYSTEM IN DEFENSE OF POPULATION AND POPULATION CENTERS

THE PROBLEM

1. The objective of this Enclosure is to evaluate the potential contribution of NIKE-ZEUS to the protection of the population and population centers of the United States.

INTRODUCTION

2. NIKE-ZEUS can potentially contribute to the defense of both the population itself and the industrial capacity of the U.S. Because the effectiveness of NIKE-ZEUS in defense of population depends greatly upon U.S. civil defense posture, the discussion will be conducted in three phases. First the general effects on our population of various nuclear attacks will be treated, together with the dependence of the results on passive defense measures. Second, the potential contribution of ZEUS in the absence of passive defense (fallout shelters) will be discussed. Finally the potential contribution of ZEUS in the presence of fallout shelters will be treated. In this last case the contribution of ZEUS to the defense of industry will be treated simultaneously with the defense of population.

DISCUSSION

VULNERABILITY OF U.S. POPULATION

3. The major weapon effect for production of population casualties is radioactive fallout from ground burst nuclear weapons, at least until such time as a very extensive and effective fallout shelter program has been implemented. The use of air burst weapons in the time period considered must be regarded as highly unlikely, except to deliberately minimize population casualties, for the following reasons:

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a. An air burst at optimal height is only more effective for blast than a ground burst for targets of hardness less than about 15 psi;

b. The benefits of optimal air burst can only be achieved if the hardness is known with some precision, and this requires a more sophisticated and less reliable fuzing system than for a ground burst;

c. For soft targets the kill probability is already essentially unity even for ground burst weapons for ICBM's with the characteristics estimated for the USSR in 1965-70;

d. The bonus advantages created by ground burst, which include destruction of hard components of a generally soft complex and disruption and denial of the use of areas for a period of time, are denied by choice of air burst; and

e. The world-wide fallout is maximized by air bursts.

4. The extreme vulnerability of civilian populations to radioactive fallout has been shown in previous WSEG studies.[1/2/] It is probably most convincingly demonstrated by purely statistical calculations in which weapon delivery within large subareas of the country is assumed to be completely random. To indicate this vulnerability fatalities have been computed on this basis for an unprepared population with no special shielding (essentially the present situation) in which only moderate use is made of existing dwellings for shelter.[3/]

1/ WSEG Research Memorandum No. 5, "Simple Formulas for Calculating the Distribution and Effects of Fallout in Large Nuclear Weapon Campaigns (with application), by Hugh Everett, III, and George E. Pugh, dated 9 January 1958, UNCLASSIFIED.
2/ WSEG Report No. 18, 1956, TOP SECRET.
3/ The method of computation used here is given in WSEG Research Memorandum No. 5. The shielding factors assumed are identical to those used for the "unprepared case" considered in that document. The differences in the results obtained are primarily due to recent increases in the estimated total radioactivity per megaton (D.A.S.A. 528).

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5. Figure 1 presents the results of this calculation. Three targeting doctrines have been chosen as illustrative of the range of possible results.

a. Targeting for which weapons are delivered uniformly at random over the entire U.S. The population fatalities resulting from this attack approximate the fatalities which would result from an attack with major emphasis on retaliatory bases together with some limited targeting of control centers and principal cities.

b. Targeting in which weapons are delivered to regions in proportion to the population in the region, which is roughly typical of an attack concentrated upon the industry and communication and transportation facilities of the U.S.

c. Targeting which seeks to maximize population fatalities by distributing the attacking weapons optimally for this purpose.

6. It is important to note that, while the model which serves as a basis to the calculation assumes that the weapons are delivered at random within each state of the U.S., the numbers of fatalities do not change significantly for an unprepared population even if the principal cities within the states are directly targeted, for the range of attack levels considered here.

7. In order to illustrate the point that these curves remain generally valid (in the absence of fallout shelters) even for direct city targeting, total casualties for a campaign which attacked cities only, with the objective of maximizing urban casualties, were calculated. The results are compared in Figure 1-A with the results of random attacks proportional to population density and optimized to maximize fatalities.4/ With respect to

4/ This campaign cannot be validly compared to the uniform case since the geographic distribution of yield as well as the objective of the attack are so different.

FIGURE 1

EFFECT OF VARIOUS TARGETING DOCTRINES AND ATTACK LEVELS ON TOTAL CASUALTIES IN U.S.A.

FIGURE 1-A

COMPARISON OF TOTAL CASUALTIES FROM DIRECT CITY ATTACK WITH RANDOM AREA FALLOUT MODEL
(Unprepared Case)

expenses, for thirty squadrons of sixty missiles each, is given as \$196.7 million per squadron, or about \$3.25 million per missile.

(U) 40. If we accept these figures for systems cost as being approximately accurate, and measure costs for MINUTEMAN missiles and NIKE-ZEUS batteries at the rate of \$3.25 million, and \$91 million respectively, then we conclude that the cost of one NIKE-ZEUS battery in a system of about 120 batteries is approximately equal to the cost of 28 MINUTEMAN missiles in a system of about 30 squadrons.

(U) 41. If one or more NIKE-ZEUS batteries are being considered as a means of defense for a number of MINUTEMAN missile sites, we can inquire as to the relative effectiveness, in terms of survival of the total MINUTEMAN force, of the installation of these batteries versus the installation of 28 more MINUTEMAN missiles for each of the proposed NIKE-ZEUS batteries. The cost of the two proposals is considered to be about the same, from the analysis of the previous paragraph.

(U) 42. To make the comparison, we suppose that the MINUTEMAN force is attacked by ballistic missiles, in such a way that the optimum use of NIKE-ZEUS batteries, as defined in paragraph 21, is possible. That is, saturation of the traffic-handling capability with cluster warheads or decoys does not occur. Efficient use of the incoming enemy missiles is assumed in that we suppose that the enemy aims a sufficient number of missiles at the defending batteries themselves, to assure himself of a high probability of penetration, before aiming at the MINUTEMAN sites being defended.

43. The NIKE-ZEUS batteries are to be hardened to 5 psi, and the MINUTEMAN sites are to be hardened to [redacted] We suppose that the only means of incapacitation of a MINUTEMAN missile is through destruction of its [redacted] psi shelter. An enemy weapon with sufficient yield and accuracy to give a high probability of kill against a [redacted] target will almost certainly destroy a 5 psi target so that penetration of a NIKE-ZEUS battery by a weapon aimed at that battery can be assumed equivalent to destruction. Table II illustrates this point for a variety of weapon characteristics.

44. The enemy tactic chosen then is to fire at each NIKE-ZEUS battery until he has achieved a high probability of penetration and destruction. The NIKE-ZEUS battery tactic is to require the enemy to fire the maximum possible number of missiles to achieve this desired probability. In the previous section, we have shown that this maximum number the enemy can be required to fire to assure himself of 90 per cent probability of penetration of a NIKE-ZEUS battery is 28 missiles. If n batteries are present, 28n will be the maximum required to assure 90 per cent probability of penetration of each battery. But excepting for missiles of extremely large yield, 28 missiles can expect to destroy at most 28 MINUTEMAN sites. Table II shows, for example, that an 8-MT missile with a 1-n.mi. standard deviation (CEP = 1.18 n.mi.) has a probability of .45 of destroying a 100-psi point target and a probability of .99 of destroying a 5-psi point target.

45. We can conclude that for the two systems of equal investment cost, n NIKE-ZEUS batteries and 28n MINUTEMAN missiles, the cost to the enemy to reduce the MINUTEMAN force level to any given quantity is greater if the 28n extra MINUTEMAN missiles have been installed than if the N NIKE-ZEUS batteries have been installed. (U)

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46. Annual operating costs for the two systems are difficult to compare, since reliable estimates of life expectancy are not available. The annual operating cost of a NIKE-ZEUS battery in a 120-battery system, excluding FAR costs but including a proportionate share of the LAR annual operating cost, but excluding training and some other factors, is about $4.5 million.[3/] The annual cost of operating a squadron of MINUTEMAN missiles will then be about $25.7 million, from Enclosure "D" of Second Annual Review, WSEG Report No. 23. If these costs are included with system costs and the systems are amortized over five years, the number of MINUTEMAN missiles which can be purchased and operated for a five-year period, for the cost of the purchase and operations of a NIKE-ZEUS battery for the same period, drops to twenty missiles.

47. On the basis of this argument, it might appear that for the purpose of increasing the surviving MINUTEMAN force level, the use of NIKE-ZEUS to defend MINUTEMAN sites is a comparable measure to the construction of more MINUTEMAN sites for fixed cost. In this case, the relative evaluation of the two competing systems would depend on other considerations, such as total amount of fallout delivered, etc. However, under the conditions of attack previously stated, the destruction of twenty MINUTEMAN missiles exacts a greater cost in enemy missiles than the destruction of a NIKE-ZEUS battery for any missile that cannot exact a kill probability of very nearly one against a 100-psi point target. For an 8 MT, 1 n.mi. standard deviation missile,

3/ The cost estimates submitted to WSEG by the Army are tentative in nature and, because of the present stage of system operational planning, do not include all possible cost items. The investment cost is reasonably complete and probably represents a major portion of the initial one-time outlay. Annual, or recurring, operating costs are not as complete and could possibly double in practice those used here in the analysis. See Appendix to Enclosure "A".

for example, one missile has a probability of 0.45 of destroying a 100-psi point target, and 4 missiles have a probability of 0.91 of destroying the target, so that 80 missiles would be required to achieve 90 per cent probability of destruction to each of 20 point targets, as compared with a maximum of 28 to achieve 90 per cent probability of destruction to the NIKE-ZEUS battery. Also, any degradation in the performance of the NIKE-ZEUS battery which could result from enemy traffic-handling saturation techniques, will further increase the degree of the discrepancy indicated.

48. The 8 MT, 1-n.mi. standard deviation missile considered above represents a very advanced capability. However, even greater accuracy and yield of Soviet ballistic missiles beyond the figure used for illustration here might occur in the period 1965-70. For such higher performance missiles, the [redacted] hardness of MINUTE-* MAN may no longer offer a satisfactory defense of these installations. To counter this event, increased hardness and the implementation of a mobility concept have been proposed. No approved Air Force plans or cost figures exist for either of these concepts.

49. Early estimates indicate that the system costs for a mobile MINUTEMAN would probably be less than twice that of the fixed hardened missile. The mobile missile might suffer some degradation in reliability and accuracy over the fixed missile. Let us suppose that for a fixed system and operation cost, fixed MINUTEMAN sites, or NIKE-ZEUS batteries to defend them, or mobile MINUTEMAN missiles, can be purchased in the ratio 20:1:10. For a fixed cost then, we could obtain 20n fixed MINUTEMAN missiles, or 20(n-x) fixed missiles and x NIKE-ZEUS batteries to defend them, or 20(n-y) fixed missiles and 10y mobile missiles. The cost in very high performance enemy ballistic missiles to destroy the missiles in these three cases is a minimum of 20n in the first case;

20(n-x)+25x in the second case, if the enemy must use 25 missiles to achieve high probability of destruction of a NIKE-ZEUS battery; and, in the third case, 20(n-y) plus an unknown quantity which would perhaps be expended in an attempt to find mobile missiles. Unless the Soviets had available a highly reliable and rapid intelligence system, the third case would leave 10y mobile missiles in locations unknown to the Soviet, from which they could be launched, or removed to other locations.

Other Missile Systems

50. The above analysis can also be applied to the ATLAS and TITAN systems. The TITAN system, like the MINUTEMAN system, will consist of [redacted] point targets, with either 1 or 3 TITAN * missiles per point. The later squadrons will consist of 9 missiles at 9 separate points. The early ATLAS squadrons will be hardened to 3 and 25 psi. Later squadrons will consist of 9 missiles in 9 separate [redacted] sites. *

51. Some of these squadrons will be located near SAC bomber bases, and so would presumably be protected by the same batteries used in defending the base. However, we will compute the value of NIKE-ZEUS defense to hardened ATLAS and TITAN squadrons as compared with the value of constructing extra ATLAS or TITAN missiles, for increasing surviving force levels, ignoring any other targets which the NIKE-ZEUS batteries might defend.

52. ATLAS costs for the later, separated, 100-psi squadrons are given in WSEG SAR Report 23, Appendix "D", as $143.9 million per squadron system cost, and $21.4 million annual operating expense, an annual cost of about $50 million, for a system amortized over 5 years. TITAN annual costs for the later, separated squadrons are the same. Using the same comparison

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20(n-x)+28x in the second case, if the enemy must use 28 missiles to achieve high probability of destruction of a NIKE-ZEUS battery; and, in the third case, 20(n-y) plus an unknown quantity which would perhaps be expended in an attempt to find mobile missiles. Unless the Soviets had available a highly reliable and rapid intelligence system, the third case would leave 10y mobile missiles in locations unknown to the Soviet, from which they could be launched, or removed to other locations.

Other Missile Systems

50. The above analysis can also be applied to the ATLAS and TITAN systems. The TITAN system, like the MINUTEMAN system, will consist of 100 psi point targets, with either 1 or 3 TITAN missiles per point. The later squadrons will consist of 9 missiles at 9 separate points. The early ATLAS squadrons will be hardened to 3 and 25 psi. Later squadrons will consist of 9 missiles in 9 separate 100 psi sites.

(U) 51. Some of these squadrons will be located near SAC bomber bases, and so would presumably be protected by the same batteries used in defending the base. However, we will compute the value of NIKE-ZEUS defense to hardened ATLAS and TITAN squadrons as compared with the value of constructing extra ATLAS or TITAN missiles, for increasing surviving force levels, ignoring any other targets which the NIKE-ZEUS batteries might defend.

(U) 52. ATLAS costs for the later, separated, 100-psi squadrons are given in WSEG SAR Report 23, Appendix "D", as \$143.9 million per squadron system cost, and \$21.4 million annual operating expense, an annual cost of about \$50 million, for a system amortized over 5 years. TITAN annual costs for the later, separated squadrons are the same. Using the same comparison

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as before, we have that for a fixed five-year cost we can procure one TITAN or ATLAS squadron for slightly more than the cost of two NIKE-ZEUS batteries.

53. As already shown, the cost in enemy missiles to penetrate each of two NIKE-ZEUS batteries with 90 per cent probability is 56 missiles. A calculation from Table II shows that for a 1-n.mi. standard deviation 8-MT missile, the cost of destroying each of nine [redacted] points with at least 90 per cent probability is 36 missiles. If the characteristics of the missile are 1-n.mi. standard deviation 4 MT, this number would climb to 54, comparable to the cost of the defending NIKE-ZEUS batteries. As the accuracy of the missile drops, the number required to destroy a hardened target increases rapidly.

54. The relative value of the two proposed methods for increasing surviving force levels would appear to depend to an extent on the performance characteristics of the attacking missile. The standard deviation of 1 n.mi. (CEP = 1.8 n.mi.) is less than that attributed to USSR ballistic missiles capabilities by NIE-11-5-58 in the period through 1966, but is not less than estimates of our own capability for this period, and should not be excluded from the realm of possibility for the years 1965-70.

DEFENSE OF SAC BOMBER BASES AND OTHER INSTALLATIONS

(U) 54. The uncertainties in the U.S. retaliatory posture and in the size and nature of the enemy ballistic missile threat, in the 1965-70 period, have been discussed in previous sections of this Enclosure. This threat will probably consist of both SLBM's and ICBM's. In this section we will indicate in more detail the ballistic missile threat to SAC bomber forces, control centers, and other military and civilian installations important in a

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retaliatory role. In general, these forces and installations divide into those for which early warning is important, such as the SAC ground alert force, and those for which it is less important, such as the non-alert force, some government centers, etc.

SLBM Threat

56. The principal threat from submarine-launched missile attack stems from the fact that such an attack could probably be delivered with virtually no warning, if no adequate system of submarine detection and control were available. With IR detection equipment available to detect missile launchings before burnout near our coast, the maximum warning time would be the time of flight of the ballistic missile, less identification and communication delay. This time of flight varies from about four minutes for a 100-n.mi. course to eleven minutes for a 1000-n.mi. course.

(U) 57. According to the 1963 SAC bomber base deployment, about 50 per cent of all SAC bases will be within six minutes time of ballistic missile flight of the 100 fathom line off the U.S. coast. Even with IR warning this time falls just on the lower edge of the present 5-15 minute period after warning within which the SAC ready-force could be launched.

(U) 58. If the NIKE-ZEUS system meets its design requirements, and can operate effectively without FAR or other warning, it might offer a valuable means of defense against the SLBM threat. This system could be especially valuable in defense of those SAC bomber bases near coastal waters. The system could serve to shoot down incoming enemy missiles, and to provide some delay time before the enemy could achieve penetration. The effectiveness of the system in accomplishing both of these objectives would depend not only on the force level of attack against the system, but also upon the traffic saturation capabilities of the attack, through

the use of cluster warheads, decoys, and close spacing of incoming missiles. The price of 28 enemy missiles, for a high probability of achieving penetration, which NIKE-ZEUS could exact if the enemy did not have such a capability, could thus be greatly reduced, as has been shown elsewhere in the paper.

59. However, if the enemy did or could not develop and deploy the necessary forces to achieve traffic-handling saturation of NIKE-ZEUS, through a submarine-launched missile attack, the NIKE-ZEUS system could perhaps raise the price of successful attack through this means beyond the ability of the enemy to pay. For example, the maximum cost of obtaining 90 per cent probability of penetration of each of 30 NIKE-ZEUS batteries, without traffic-handling saturation, would be 840 missiles, or 28 missiles per battery. For 60 batteries, 1680 missiles would be required. Such a large force level would increase the number of missile-launching submarines that would have to be deployed, with the consequent greater probability of giving strategic warning.

60. Use of air alert for SAC bombers would also serve as a means of preserving the ready-air force from surprise SLBM attack. Costs for air alert for the FY 1964 programmed force of 16 B-52 wings are given in WSEG Second Annual Review, Report No. 23, Enclosure "D". These costs, including extra investment and operating costs for the KC-135's supporting the bomber force, are given in Table IV.

TABLE IV

COSTS FOR AIR ALERT, 16 B-52 WINGS (1964)

24-Hour Sorties Per Day Per Wing	Additional Investment for 16 Wings (million $)	Additional Annual Cost for 16 Wings (million $)
6	19.2	720
12	711.8	2074.6
18	1438.0	3357

61. Bombers on air alert have a high probability of being able to fly a retaliatory mission even under the circumstance that the NIKE-ZEUS system would fail to prevent the destruction of SAC ground forces by surprise attack. However, NIKE-ZEUS would have capability to defend non-alert ground forces, cities, etc., which air alert forces could do only indirectly through the threat of retaliation.

ICBM Threat

62. A large ICBM force launched from the USSR or its satellites against CONUS would probably be detected by an operating BMEWS system, which would provide at least fifteen minutes warning time to any CONUS site, if communication delays were not excessive. This time would probably be sufficient to allow the ground ready force to escape ICBM attack. The remaining two thirds of the bomber force could not be launched on a retaliatory mission for several hours after warning, although dispersal of part of this force in a shorter time might be feasible.

63. Protection for other installations which cannot escape ICBM attack could be provided by NIKE-ZEUS, however. Targets such as government control centers, Army bases, etc., could not easily be protected by other means, in many cases. The ability of the enemy to penetrate these defenses would depend on the traffic-handling saturation techniques he could employ and the force levels he could use in his attack. Levels required to achieve 90 per cent probability of penetration of a NIKE-ZEUS battery could vary from one missile with a cluster of several warheads and decoys, to 28, a variation in force level which includes probable USSR capabilities in the period 1965-1970.

SUMMARY AND CONCLUSIONS

64. In this Enclosure we have examined the potential contribution of NIKE-ZEUS to the defense of the various portions of the CONUS retaliatory system for the period 1965-1970.

65. The NIKE-ZEUS system was examined to determine the firing procedure that would maximize the number of missiles which the enemy must send into the defensive area of a battery to achieve 90 per cent probability of penetration. This maximum is twenty-eight missiles, if no traffic-handling saturation is employed. Saturation techniques such as cluster warheads, decoys, or close missile spacing in time, could reduce this number greatly.

66. In examination of the value of NIKE-ZEUS in the defense of hardened MINUTEMAN sites, we examined the surviving MINUTEMAN force levels under two procedures of approximately equal cost for any given enemy threat magnitude and characteristics:

a. Construction of more hardened MINUTEMAN sites

b. Deployment of NIKE-ZEUS to defend a number of these sites.

For all reasonable estimated enemy missile characteristics and any force magnitudes, procedure a results in a considerably greater surviving MINUTEMAN force level than procedure b.

U 67. A similar examination of ATLAS and TITAN sites, on the same basis, leads to the conclusion that the relative merits of procedures a and b to increase surviving ATLAS and TITAN force levels depend on other factors, such as the enemy threat in yield, CEP, decoys, cluster warheads, etc., over reasonable estimates for these characteristics in the period 1965-1970.

U 68. The NIKE-ZEUS system may offer a defense of the SAC ground ready-force from SLBM attack, in the absence of extensive air

alert or of an adequate method of submarine detection and control. The system may also offer a defense of SAC non-ready forces, control centers, and other retaliatory installations, from SLBM and ICBM attack. Whether this is the most economical method of defending the retaliatory capabilities has not been examined. The effectiveness of NIKE-ZEUS for this purpose depends on the characteristics of the enemy threat, particularly with regard to his possible development and use of decoys and cluster warheads as a means of penetration.

ENCLOSURE "D"

ESTIMATED CAPABILITIES OF A NIKE-ZEUS FIRING UNIT AGAINST POSSIBLE ICBM AND IRBM THREATS

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ENCLOSURE "D"

ESTIMATED CAPABILITIES OF A NIKE-ZEUS FIRING UNIT AGAINST POSSIBLE ICBM AND IRBM THREATS

PROBLEM

1. To make reasonable estimates of weapons effectiveness parameters (e.g., coverages, simultaneous and extended engagement capacities, decoy discrimination capabilities) which a typical NIKE-ZEUS firing unit might achieve against possible ballistic missile threats (i.e., types of warheads and decoys) in the post-1964 period.

SCOPE AND METHOD OF APPROACH

2. The necessity of considering decoys of various types as an element of the ballistic missile threat requires classification of the ZEUS firing unit as presently designed into several models of differing capabilities. The effectiveness of these with respect to possible threats is discussed in a general way,[1/] so that realistic coverage and engagement capacities against particular threats can be roughly estimated. Such considerations are applied to selecting reasonable parameters for a simple simulation model, indicating wherein approximations are made.

DISCUSSION

INTRODUCTION

3. ZEUS firing unit capabilities in terms of effectiveness parameters such as engagement capacity and coverage are sensitive to threat characteristics like yield and CEP only to the extent that these may interact with and affect the more difficult-to-predict threat characteristics of decoys, cluster warheads, or ECM. Of course, both types of threat characteristics, as well

1/ This is necessary to set the stage for detailed intercept calculations, which can then establish effectiveness parameters quantitatively. We have not made such calculations, but in some cases have anticipated their results for the purposes of this project, since in many instances the inaccuracies involved are minor in comparison to the uncertainties of realizing the postulated conditions.

as additional factors which enter when system deployment is considered, will determine the effectiveness of an attack against a given target in a specific situation.

4. There is some uncertainty both as to what may be technically and economically feasible for advanced threats, and as to what can be achieved by some schemes of decoy recognition. Since the ZEUS design is sufficiently flexible to incorporate schemes whose evaluation is not now complete, and since any determination of the likelihood of particular enemy threats (as opposed to their feasibility) must be associated with tenuous arguments involving intent and strategy, it seems desirable to develop the ZEUS effectiveness parameters for several combinations of a few limiting ZEUS capability levels against a few limiting cases of possible threats, pointing out the assumptions made and indicating whether these correspond to proven capabilities, present state-of-the-art capabilities, or extrapolated state-of the-art possibilities. Table I gives an outline of the areas considered from this viewpoint.

5. Continuing studies[2/] of the ZEUS system are being conducted to determine the optimum composition of a firing unit (i.e., the number and ratio of TTR's, MTR's, and missiles) as well as the optimum deployments and firing doctrines for these units, for various assumptions. As inputs, these studies use ranges of parameters (such as missile reliability, TTR recycle times, number and values of defended areas, enemy ICBM stockpile and arrival rates, etc.) whose actual values are strongly dependent on our technical capabilities, the value of the defended objects, and the enemy threat characteristics. It is necessary to select compromises in system composition and firing doctrine (including salvo size) which cover a large range of threats fairly well

2/ By BTL, AOMC, and NORAD.

TABLE I

ZEUS Decoy Discrimination Capability (in order of increasing potential for improved effectiveness parameters)	Threat Types[a] (in order of probable ease of technical achievement)
1. Those based on re-entry phenomena	1. Slow warhead (low ballistic coefficient, $\beta = \frac{W}{C_D A} = 200$ lb ft^{-2} high radar cross-section, $\sigma = 0.5$ m^2).
a. Slow-down (no doubt of feasibility and range of application)	a. Plus fragmented tankage
b. Slow-down plus ionization, amplitude, infrared and optical or other phenomena (further experimentation required to establish feasibility and range of application).	b. Plus fragmented tankage and balloons.
	c. Plus fragmented tankage, balloons, and heavy decoys.
2. Those based on out-of-atmosphere phenomena	2. Fast warhead (high ballistic coefficient, $\beta = 1000$ lb ft^{-2}; low radar cross section $\sigma = 0.02$ m^2).
a. "Stand out" phenomena from trajectory analysis (seem difficult and applicable only to special situations)	a. Plus fragmented tankage and balloons.
b. Signature from scintillation, spectrum analysis, polarization, etc. (further experimentation required to determine range of applicability). Probably effective against tank fragments, but balloon camouflage of warhead and decoys (veiling) might invalidate these outside the atmosphere unless (c) were successfully employed.	b. Plus fragmented tankage, balloons, and heavy decoys.
	3. Multiple or cluster warhead (high ballistic coefficients, low radar cross sections). Plus fragmented tankage and balloons.
c. Use of precursor burst (perhaps desirable to destroy or detect light decoys). Use of such bursts (or of other missile aids) for more sophisticated tests, including nuclear effects, against heavy decoys is problematical, but now appears to require excessively complex instrumentation.	

a/ Each of the three threat types indicated is subject to two further classifications--whether low or high re-entry angle, and whether ICBM or sea-launched IRBM. Electronic countermeasures are considered a secondary threat (see paragraphs 19-25).

ENCLOSURE "D"

ESTIMATED CAPABILITIES OF A NIKE-ZEUS FIRING UNIT AGAINST POSSIBLE ICBM AND IRBM THREATS

rather than to optimize the system against particular threats. 3/ Thus, throughout our considerations we shall use the firing unit composition of 3:10:50 (No. TTR's or DDR's:MTR's:AMM's) 4/ and, in accordance with the discussion of paragraph 4, shall arrive at limiting values for the capabilities of such a composition. Obviously changes in this firing unit composition which modify the effectiveness parameters of single firing units could have much the same over-all effect as changes in the number of units deployed, although the former procedure could have cost advantages over the latter. As the saturation aspects of the threat become more serious (e.g., with cluster warheads), it may be desirable to increase the number of TTR's, MTR's, and missiles per firing unit, 5/ as well as the number of firing units allocated to a local defense center.

MODELS OF NIKE-ZEUS FIRING UNIT CHARACTERISTICS

6. In attempting to narrow down the number of representative models of a ZEUS firing unit (of fixed composition) which must be considered in illustrating representative decoy discrimination capabilities, 6/ a reasonable division appears to result in three models:

a. Model A relying only on atmospheric slow-down. The capabilities of this model can be stated with assurance, and

3/ A TTR (and slaved DDR) is required to track each target engaged; thus, the number of TTR's and their "tie-up" or recycling time will limit engagement capacity in a simultaneous or saturation-type attack. The number of MTR's determines how many ZEUS missiles can be directed in a salvo against a single target (fire capacity), and thus greatly influences kill probability. In protracted attacks, the total number of missiles available may be limiting.

4/ The same composition as is used for funding purposes. Salvos of three missiles each will also be assumed, since this is consistent with the 3:10 ratio of TTR to MTR's.

5/ We understand that compatibility for using twice the number of TTR's, MTR's, and missiles (per firing unit) that we have assumed is being built in the system (with modular type design, this is not difficult).

6/ Nearly all such capabilities will be found in the firing unit since only its radars (TTR and DDR) can have the resolution and observation time required.

there is no doubt that they are attainable. Its chief weaknesses are that it can intercept only below discrimination altitudes (e.g., 200,000 ft), and that it must fire on as many heavy decoys as the enemy can include which have reasonable radar cross sections and ballistic coefficients large enough to fall in the warhead category. It represents a minimum capability for ZEUS against a decoy threat.[7]

b. Model B having the capabilities of Model A plus at least one further successful criterion[8] based on re-entry phenomena which are sensitive to the weight of the re-entering body. This model would require the enemy decoys to approach the weight of the warhead, or, practically speaking, would eliminate any necessity of firing on decoys, but would still not permit intercepts outside the atmosphere. Thus the coverage of the full 75-mile horizontal range would still be subject to launch-before-discrimination uncertainties if cluster warheads were employed in unpredictable fashion.

7/ This minimum capability retains its limited effectiveness out to maximum horizontal range (conservatively limited at present to 75 n.mi. by guidance accuracy and lethal radius). This is accomplished by launching missiles before discrimination toward the area in which the discrimination will occur, with obvious uncertainties in the number of missiles which should be launched. There is little doubt that launch before discrimination will always be utilized, since it may increase engagement capability by one object with no risk of wasted missiles, or by three objects with risk of waste of two salvos if these are dispatched to a single cloud which proves to contain no decoys or no element of a cluster warhead. If missiles were not launched until discrimination indicated how many were needed, the area which could be defended would be reduced in size. In this reduced area around the firing unit, whether launch is before or after discrimination, there is a chance (for slower warheads, smaller re-entry angles, or IRBM) that a single TTR can guide two salvos to intercept before minimum acceptable altitude is reached.

8/ Or perhaps several complementary criteria, including those based on optical and IR phenomena. Although resolution is achieved in angle optically and in range by radar, precise angular measurement by radar of the range-resolved objects (as provided for ZEUS) would allow correlation between the two types of data to be achieved easily if the optical instrumentation were on the ground with the radar. The scheme would be subject to weather uncertainty, however.

The attainment of the criteria required to realize the capabilities of Model B appears possible but not certain, and further re-entry decoy tests are required to determine if these criteria can be countermeasured.

c. Model C having the capabilities of Model B plus a variety of radar signature tests (perhaps combined with precursor burst) for the out-of-the-atmosphere. If these were successful, the system could be effective to its maximum range against decoyed threats, would have improved traffic-handling capability for saturation attacks (due to possibility of intercepts beginning at 75 miles altitude), and would then represent the maximum capability for ZEUS as now conceived.[9]

7. The extraction of the information required by Model C (which includes all capabilities of Models A and B) is primarily a matter of data processing, and the type of facilities necessary for this are to be provided in the ZEUS system. The incorporation of as many criteria as can be proven will at least complicate the enemy's problem and result in capabilities against likely threats somewhere between that of Model A and a completely successful Model C. We shall denote our best estimate of such capabilities as Model D. These models, together with the threat models to be discussed next, are summarized in Table II.

MODELS OF ICBM AND IRBM THREAT TECHNICAL CHARACTERISTICS

8. In attempting to narrow down the number of representative models of ICBM warhead and countermeasure threats which need be considered, we shall rule out maneuvering warheads and maneuvering

9/ Because radar signatures would have to be attained at greater ranges than for re-entry discrimination, a greater incentive would exist for use of ECM against the DDR by the enemy (see paragraphs 19-25).

TABLE II

SUMMARY OF POSTULATED MODELS

ZEUS CAPABILITY MODELS a/

1. Model A

   Assumes only aerodynamic slowdown discrimination can be successfully employed against decoys. Gives a minimum capability.

2. Model B

   Assumes aerodynamic slowdown plus at least one other re-entry phenomenon can be employed against decoys in such manner as to force them to approach warhead weights. Does not permit interception out of the atmosphere.

3. Model C

   Assumes out-of-atmosphere decoy discrimination is successful either through use of precursor bursts or other missile assists in space (Model C_1) or by means of radar or other signature (Model C_2)

4. Model D

   Our best estimate of actual capabilities likely to be attained by ZEUS. These will be greater than those found for Model A and less than those found for Model C.

THREAT MODELS b/

1. Model A

   Slow ICBM warheads (β = 200 lb. ft^{-2}) of medium radar cross-section ($\delta = 0.5m^2$).

2. Model B

   Fast ICBM warheads (β = 1000) of low radar cross-section (δ = .02).

3. Model C

   IRBM warheads (β = 700, δ = 0.1) with 1000-n.mi. maximum range.

4. Model D

   IRBM warheads (β = 700, δ = 0.1) with 200 n.mi. maximum range.

5. Model E

   Cluster warheads for ICBM having 10 subwarheads of 200 KT yield each.

a/ All ZEUS models assume design specifications are met. In terms of physical equipment all models are identical. They differ in assumptions as to the degree of success realized by the various means of decoy discrimination which are incorporated.

b/ All Threat Models may be accompanied by fragmented tankage, balloons, and heavy decoys in appropriate numbers (see text).

decoys. The ZEUS command guidance system is a closed loop with sufficiently short time constant so that the ballistic warhead would have to exceed the AMM maneuver capability (greater than 20 g below 100,000 feet) either for a considerable time or at a rather precise moment (two to four seconds before intercept) to degrade kill probability appreciably. The cost of the former would appear excessive in payload compared to other uses that might be made of it, and the latter (which might be accomplished by a drag skirt) would have a low probability of occurring at the proper time.

Decoys

9. Chaff, balloons, and most tank fragments are a class of decoys called light decoys which cannot be expected to deceive atmospheric slow-down discrimination, but may be effective against out-of-atmosphere discrimination. Chaff would appear to be the poorest of these aerodynamically as well as from a radar signature viewpoint, in addition to having unsolved problems of dispersal out of atmosphere. Tank fragments can be obtained relatively easily, but probably can be discriminated out of atmosphere. Balloons have only a small weight penalty. If they were designed to appear and behave like nose cones, or were used in the "veiled" threat to cover the nose cone as well as decoys, out-of-atmosphere discrimination would seem to require precursor bursts and/or techniques not now feasible.

10. In order to overcome discrimination by atmospheric slow-down, "heavy" decoys must be employed. When these are designed to survive and match the ballistic coefficient of the closest feasible nose cone, and at the same time exhibit comparable radar cross section out of atmosphere, the relatively restricted number which

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can be included per warhead, plus the possibility that other re-entry phenomena[10] may still allow them to be discriminated, make the more expensive multiple or cluster warhead a possibility which must be considered, especially if industrial areas or population rather than hardened bases are the targets.

11. In attempting to assess technical characteristics of future enemy threats, all positive intelligence information and such aspects of the enemy's problem as are different from ours should be considered in order to avoid simple mirror-imaging of our own offensive development program. It is generally believed that if an attack were initiated by an enemy he would give high priority to striking our offensive forces, and it seems reasonable that in any event he would desire to stockpile missiles capable of the accuracy required for this. Since the Russians appear to have had a more leisurely approach to the solution of re-entry problems, and are known to have experimented with ablating nose cones, their early nose cones could be of the ablating type with fairly high ballistic coefficient (say β = 700) coming in at relatively high angles[11] (around 45°). This might be the only type developed in order to obtain large stockpiles more quickly. On the other hand, if Russian psychology leads to the development of missiles primarily for blackmail or retaliatory purposes, fast re-entry bodies might seem advantageous only in case they were expected to encounter ballistic

10/ In this area particularly (re-entry gas-dynamic phenomena including dissociation, ionization, radiation, and plasma effects) present knowledge is incomplete, preventing a clear picture as to whether the complicated phenomena taking place in the region below where balloons burn up can best be utilized by the offense or the defense. Fundamentally these phenomena would seem to complicate the offense's problem by providing further parameters which must be matched between decoy and nose cone, some of which may be difficult to match between unequal masses.

11/ The higher angles (30-60°; 23° is minimum energy trajectory for a 5500-n.mi. ICBM) and "slicker" missiles (β > 200) give less time for terminal defense action and less error from terminal atmospheric conditions. However, higher angles give longer total flight times and more warning from BMEWS-type systems.

missile defense of population.[12] In any event, threats No. 1 and No. 2 of Table I appear to bracket the reasonably expected values for nose cone ballistic coefficients. In our models we shall consider each of these limiting values for ICBM's and shall choose for IRBM's an intermediate value of $\beta = 700$ with a radar cross section $\sigma = 0.1\ m^2$. In both IRBM and ICBM threats we shall consider two possible re-entry angles -- $22\frac{1}{2}^\circ$ and 45°.

12. Having established the primary parameters β, σ, and re-entry angle for what we shall call Threat Models A (slow re-entry 5500-n.mi. ICBM), B (fast re-entry 5500-n.mi. ICBM), C (intermediate re-entry 1000-n.mi. IRBM), and D (intermediate re-entry 200-n.mi. IRBM,[13] it remains to endow these with reasonable countermeasure capabilities. The enemy's objective is to provide decoys that must be fired upon because they cannot be recognized, or to delay the recognition of these to as low altitudes as possible. Perhaps 100 tank fragments of controlled size and appreciable cross section are obtainable at a weight penalty of 200 pounds (uncontrolled fragmentation might cost 35 pounds). These probably will be used with all Threat Models even though ZEUS should be able to discriminate them by radar signature (they will slow down and burn up on re-entry). There may be a few bonus heavy decoys (e.g., motor and instrument components) which will survive re-entry but which also can probably be discriminated by radar signature. Thus with ZEUS as designed, tank fragments, etc., would seem to constitute primarily a nuisance which would not decrease the effective maximum range of intercept (75 miles) if they can be discriminated by radar signature beyond about 125 miles (for missile launch before discrimination) or about 300 miles (for launch after discrimination).

12/ In the absence of intelligence information of high confidence, the defense (especially of population) probably could not afford to assume that only the fastest object in a decoy cloud was a nose cone if there were also other objects with ballistic coefficients which were still nose cone possibilities, This at least partially nullifies the advantage a slow re-entry body might be expected to have from the greater number of heavy decoys which might accompany it.

13/ We shall return presently to a cluster warhead threat Model E.

They would, however, tie up the tracking radar for some additional time, thus reducing the engagement capacity under certain conditions of sustained high density attack (see paragraphs 36-38).

13. More serious in reducing unrestricted coverage 14/ and fire-power would be the inclusion of balloons of a type which could not be discriminated by signature. Since these could be discriminated by aerodynamic slow-down between altitudes of 300,000 and 400,000 feet, they would have a similar but less severe effect in reducing coverage and engagement capacity as do discriminable heavy decoys (see paragraphs 36-38). However, it is possible that a precursor burst could lessen this degradation considerably by either destroying balloons or imparting sufficient momentum to them outside the atmosphere to enable their recognition as light decoys. Such balloons might be obtained for two to five pounds each, including ejection mechanisms, on all Threat Models. There would seem little point to including more than 100 of these if properly dispersed, 15/ since this would probably be sufficient to accomplish as much as a larger number.

14. Heavy decoys are made heavy by the requirement for re-entry survival as well as for approximately matching nose cone aerodynamic slow-down and out-of-atmosphere radar cross section. They have (1) the disadvantage of weight over balloons, (2) the advantages of being less susceptible to destruction or discrimination by precursor bursts, and of delaying recognition by aerodynamic slow-down to lower altitudes (200,000 feet for $\beta = 20$), and (3) the hope of preventing discrimination even at low altitudes (for $\beta > 20$). Whether this hope can be realized depends on re-entry cross section, signature, and radiation phenomena not now fully

14/ We shall use the term "unrestricted coverage" to refer to coverage attainable with launch after discrimination (see footnote 7).

15/ Unless it seemed profitable to attempt to saturate the DDR tracking capability in order to relieve the requirement for heavy decoys to match radar signature and cross section out of the atmosphere.

understood, and must await further tests. Meanwhile we can only give some estimates from pre-design studies of the weight penalty required for decoys which might do a fair job of matching aerodynamic and radar characteristics outside the atmosphere. Ring, cone, and dart shapes seem to be preferred, with weight estimates for the best of these varying from 20 to 200 pounds.[16] Since the radar cross section tends to decrease with increasing ballistic coefficient β, and since some decoys with lower β could be included with high β nose cones, the decoy weight penalties associated with high β nose cones are perhaps not as great by comparison with low β nose cones as might be expected. We shall somewhat arbitrarily select for our Threat Models A and B 50 and 75 pounds respectively as the average weight required per heavy decoy, including ejection mechanisms, safety and arming devices, etc.

15. In the speculative area of the weight which might be devoted to decoy countermeasures per ICBM, we need be no more accurate than in guessing the weight per decoy, since the purpose of the estimates is to allow determination of a reasonable figure for the number of heavy decoys per nose cone -- a figure which probably should be parameterized against weight in any case. If we choose 2,000 pounds as the weight allocated to decoys per ICBM, 600 of this might be allocated to balloons and tankage fragmentation, giving about 20 and 30 heavy decoys per ICBM for Threat Models B and A respectively. For the IRBM space and weight are more costly, and by comparison about five heavy decoys for IRBM for Threat Model C appear reasonable, with perhaps twenty-five balloons. It is emphasized that these are purely illustrative capability estimates based on untested pre-design studies and an arbitrary weight devoted to decoys.

16/ The spread and in particular the lower limit here are sensitive to the still undetermined discrimination capabilities in the transition region from outside to inside the sensible atmosphere.

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Cluster Warheads

16. Two possible reasons for employing several warheads in a cluster would be to obtain an impact pattern giving more blast damage and local fallout casualties per total yield against soft, extended targets, and to provide an alternative or assist to decoys in saturating active defenses. According to a pre-design study by Convair,17/ to eject the warheads at any time other than after burnout and before separation while the missile is still under vernier rocket control may prove excessively costly in weight, complexity, and reliability. To solve the problems of accuracy for individual warheads in a cluster may also prove difficult. However, even without these refinements, the advantages of cluster warheads against a saturable defense system may be considerable.18/

17. On the basis of tested warheads and an over-all weight allowance of 2000 pounds, DASA19/ gives the estimates shown in Table III as being within U.S. capability to develop now. In these estimates it was assumed that the nuclear system weight should not exceed approximately [redacted] the total allowable cluster warhead weight in order to permit inclusion of material required for aerodynamic shape and re-entry body protection. Necessary auxiliary devices are included; neutron shielding or provision for re-entry attitude control are not. With no further testing, it is projected that the yield of the XW-54 could be increased [redacted] with the accompanying numbers in Table III remaining the same. With further testing, future possibility estimates range to [redacted]

17/ Semi-annual Technical Summary Report, 1 December-31 May 1959, ARPA Order No. 37-59, Air Force Contract No. AF 18(600)-1843.
18/ These are bought at a price of fissionable material almost proportional to the number of sub-warheads. Heavy decoys, if successful, would probably be the least expensive method for saturating the defense.
19/ Commication from Defense Atomic Support Agency (DASA).

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capabilities for 2000 pound total weight. These represent about the maximum nuclear system yields per unit weight which may be expected without a major scientific breakthrough. In all cases (with or without further testing) approximately twice the indicated number of sub-warheads could be achieved for 5000 pounds total weight.

TABLE III

DASA ESTIMATES OF POSSIBLE SUB-WARHEAD COMBINATIONS FOR A 2000 POUND CLUSTER WARHEAD WEIGHT USING TESTED WARHEADS

Number Sub-warheads/Cluster	Type	Weight[a]	Yield[a]
3	XW-50	410 lb	[redacted]
3, 4[b]	[redacted]	325 lb	[redacted]
7	[redacted]	205 lb	[redacted]
6, 14[b]	XW-54	50 lb	[redacted]

a/ Per sub-warhead.
b/ The two numbers correspond to different packaging.

18. Should the Soviets choose to develop cluster warheads now, it might be reasonable to ascribe to them an operational capability by the time NIKE-ZEUS becomes operational similar to or greater than that given in Table II -- greater if their missiles were capable of supporting higher payloads. During the 1965-70 period, they could probably realize a cluster warhead with ten sub-warheads of 200 ~~MT~~ KT yield each. This we shall designate as Threat Model E, and use in illustrative calculations in Enclosure "B".

Electronic Countermeasures and Camouflage

19. Although side-lobe jamming of ZEUS-type radars from airborne jammers within line-of-sight would be technically feasible, it makes little military sense in view of the desire to preserve the surprise element which is one of the most attractive attributes of ballistic missile attack, in view of the uncertainty of survival against aircraft defense, and in view of more profitable missions

that surviving aircraft might perform.[20] Jamming without line-of-sight access is impractical. Hence, to be most effective, ECM efforts will be confined to jamming from the nose cone or accompanying decoys. Although problems of weight, reliability, and complexity seem to favor decoys over ECM as a penetration aid, ECM in addition to decoys might be included in advanced threats.

20. Even with average jamming powers of [redacted] watts at X-band, it appears that the jammer would have to be within a few hundred feet of the ZEUS missile to hold off burst order or other commands.[21] The distance between the jammer and missile would actually be about [redacted] feet at the time of reception of burst command from the MTR because of the fixed delay in the burst circuit. Thus jamming the missile communication link is not a profitable tactic for the enemy.

21. Jamming of forward and local acquisition radars, because of their tunability would require either barrage jamming or automatically tuned spot jammers to cover . Since either the forward acquisition or one of perhaps several local acquisition radars can furnish acquisition data to a firing unit, it is unlikely that all available acquisition data sources could be simultaneously jammed. Even if it were, angle information on the jammer could still allow the TTR to acquire.

22. The TTR will rely on pulse-to-pulse frequency shift over the entire 5250 to 5750 mcps band to force barrage jamming over this range. The TTR's chief contribution to decoy discrimination is to place the DDR on the decoy cloud; it can do this by angle

20/ Jamming from low level satellites also seems not especially attractive because of coordination problems among others (ZEUS anti-satellite capabilities, if developed, might be used against satellites during hostilities).

21/ In the atmosphere, this distance might be decreased further by attenuation by the ionized surroundings of the ICBM, or by impairment of the efficiency of the radiating device by re-entry effects.

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tracking the jammer. To allow full range intercept, the TTR need overcome the jamming at a minimum range of 125 miles (provided the DDR functions normally); this could be done against a 200-watt jammer (0.4 watts/mc) for a 0.1 m^2 cross section target. If re-entry discrimination (with attendant restrictions on coverage and firepower) were required, the jammer would have to exceed 2000 watts in order to lower burst altitude, if indeed the problems of survival and radiation through ionized layers on re-entry could be solved.

23. Enemy jamming probably could realize its maximum effectiveness when directed against the DDR. This is expected to employ initially a 20-megawatt, 20-microsecond transmitter (average power 40 kilowatts) in the 1270-1400 mcps region, with capability of eventual increase to 60 megawatts and 60 microseconds (range resolution of better than 40 yards by Chirp techniques). As the decoy cloud decreases in range, the beam width changes from 5° to 20° to maintain a 25-mile diameter field of view. To attain full 75-mile coverage, this radar is required to overcome jamming at a 350-mile range for launching after discrimination, and at 175 miles for launching before discrimination. Pulse-to-pulse frequency change is employed, and again interference with re-entry discrimination may be difficult because of jammer radiation problems in this region.[22]

24. In summary, as long as decoys are able to restrict the ZEUS intercept coverage and firepower, it appears that ECM of the power

22/ One tactic against such jamming might be the use of a modification similar in principle to the PARADE system developed by Sylvania for NIKE-HERCULES whereby two TTR's could use passive triangulation to fire precursor bursts at the jammers. Another longer lead-time CCM might be development of a phased-array antenna to allow use of multiple narrow beams for the DDR. If this same antenna could perform the functions of the TTR's and MTR's, appreciable improvements in simultaneous engagement capacity might result.

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required to further hamper the defense might be impractical.[23/] If effective solutions to the out-of-atmosphere decoy problem become available, development and use of ECM would appear profitable to the enemy, and an ECM-ECCM battle would result.

25. Related to ECM in that its purpose is also to reduce effective radar range is the use of camouflage material to decrease the radar cross section. Such material cannot be expected to survive re-entry;[24/] its weight penalty would be less at TTR frequencies than at DDR or LAR and FAR frequencies (MTR's track a beacon; FAR's and LAR's may track decoy clouds). It could give appreciable reduction (10 db or more) in the comparatively large cross sections corresponding to the side aspects of the nose cone. However, the smaller nose-on cross sections are the ones employed in discussing ZEUS capabilities, since these are more pertinent to the end-game, and since with careful shaping (not inconsistent with obtaining high β) the side-aspect cross sections can be made to approach the nose-on values. To some extent these two methods of reducing cross section (shaping and camouflage) which employ different principles are alternatives, and it appears doubtful that camouflage material can be used to appreciably reduce the nose-on or side-aspect cross section over that obtained by careful shaping and assumed in Model B. Since range decreases only as the fourth root of cross section, it does not appear likely that the obtainable reduction in TTR or DDR range would seriously degrade the ZEUS system.

Effects of Nuclear Bursts

26. By creating what is essentially an artificial ionosphere, high altitude nuclear bursts give rise to attenuation, refraction, and reflection effects which could degrade ZEUS performance. The

23/ In normal course of development we may expect modifications increasing ZEUS radar powers, particularly if its anti-satellite capability were to be developed and implemented.

24/ There may be problems of survival at launch for lower frequency camouflage.

reliability of prediction of the magnitude and duration of these effects has been greatly improved over the past year as a result of clarification of theoretical interpretations and comparison with incomplete experimental data from tests. However, until gaps in experimental knowledge are filled, and further clarification of the relative importance of the contributions of various phenomena at different altitudes in establishing electron concentrations is provided, such estimates can only be considered preliminary. The fact that the BTL and RAND estimates may agree within a factor of two is not a valid reason for accepting either as being precise to better than an order of magnitude, considering the range of phenomena involved.

27. In view of the uncertainty of the basic data from which effects on the ZEUS system must be calculated, a logical approach might reverse a cause and effect calculation procedure to set up first the effects which can be tolerated, and then see how the estimated effects compare with these (this is possible at least for simpler effects such as blackout and ray-bending). There seem to be several general types of effects -- loss of signal from absorption or reflection (blackout), ray-bending and path-length effects due to refraction (affecting position accuracy), auroral clutter and ARGUS noise, and finally perhaps more subtle effects resulting from time fluctuations of these. At present it is considered by BTL that blackout probably represents the most serious of these. All effects decrease with the square of the frequency, and hence will degrade the FAR and LAR most, the DDR and TTR less by factors of 7 and 100 respectively.

28. In connection with the FAR and LAR, a criterion has been used consisting of the distance over which 10 db attenuation is experienced 10 seconds after burst. Ten db is an estimate of the attenuation (fading) that could be tolerated on a typical established track without loss of track. It would decrease initial

detection range by 44 per cent; however, during 10 seconds the ICBM will have traveled only 40 miles, and initial detection range will than rapidly increase. A lapse of acquisition data for this time would be of marginal concern to the system -- far less, e.g., than having to wait for re-entry discrimination.25/ Using current interpretations of data, BTL calculates that a ZEUS burst [redacted] at 250,000-foot altitude would create a 25-mile maximum distance for 10 db attentuation (two-way) at 10 seconds, and an 8-mile distance at 125,000 feet.26/ Above and below these altitudes the effects are believed to decrease in magnitude and/or time. These distances correspond to angles between about 5 and 35°, depending on range of burst (from 20 to 75 miles; the worst cases of 22° for 125,000-ft altitude and 35° for 250,000-ft altitude correspond to bursts directly above the LAR). However, in planned deployment a target would have to be blacked out from at least a FAR and LAR (separated by roughly 500 miles) simultaneously to prevent acquisition, and in most cases from several LAR's as well.

29. The same sort of data indicate that a TTR with its normal time constants probably would have no difficulty in maintaining track on another target in the burst vicinity since at TTR frequency a decreasing 10 db attenuation would be reached in a second about a mile from burst, and the target will have moved a comparable distance in the same time. A 4-mile diameter, 10 db, 10-second blind spot to DDR's will exist about the burst. A precursor burst would probably be too high to give this effect. Bursts in

25/ Acquisition should take place at minimum ranges of about 125, 200, and 275 miles for re-entry discrimination, out-of-atmosphere discrimination, and precursor burst (if done by TTR terminal guidance), respectively. If a TTR were available, acquisition would be accomplished at maximum TTR range (400 miles on a 0.1 m^2 target with a traveling wave tube (TWT) receiver; 600 miles with MASER). Precursor bursts for the more stringent case (as far as engagement capacity is concerned) of high angle re-entry would be too high to cause serious blackout (according to present knowledge).

26/ These distances will have shrunk to the order of a mile after 100 seconds.

the region from mid-intercept to maximum ranges would exist if extra-atmospheric discrimination had been successful, but TTR's (not susceptible to blinding) would already have been assigned to other warheads in the cloud, if any. There is a chance that extra-atmospheric discrimination of at least parts of a following cloud could be interfered with for a time of the order of 10 seconds (objects would traverse the 4-mile distance in a second). In deployments of more than one firing unit this could be minimized by assignment doctrine. If the initial burst had to await re-entry discrimination, again it could not interfere with discrimination within the cloud, but might delay out-of-atmosphere discrimination of a following cloud appropriately timed and positioned. If extra-atmospheric discrimination had not sufficed for the first cloud, it might not also for the second. In this case only an appropriately positioned close-following cloud (say the order of 10-seconds separation) would be in danger of evading discrimination due to DDR blackout, and this might be avoided by proper firing unit assignment. If only one firing unit were available, then the 35-second recycle time of a TTR-DDR combination which we use in a later section to arrive at engagement capacities might in some cases be increased to perhaps 50 seconds, with corresponding reduction in steady state engagement capacity.

30. Ray-bending phenomena seem to have received less attention in general than blackout phenomena. The LAR pointing error from this source can be up to 5 mils (0.3°) before requiring a search by the 10 mil (0.6°) TTR beam when locking on a single object. A decoy cloud subtends much larger angles, and which object the TTR locks on initially is not important; however, since the TTR beam subtends only 3 miles at 300 miles range, TTR search before lock-on might be required even here if bending errors exceeded 5 mils (a spiral TTR search might also be required for "low-altitude" anti-aircraft capability using the hardened LAR). Potentially this 5 mil tolerable error before search is required could be increased to 45 (2.5°) by employing the 5° DDR beam. Thus there seem to be

ways of solving ray-bending effects on the acquisition problem to the extent that blackout as discussed above then becomes the bottleneck.

31. The other possibility of degradation due to ray-bending stems from the different frequencies of the TTR (5500 mcps) and MTR (9000 mcps). Since the square of the frequency ratio is roughly 3, the final error[27/] due to the different bending of MTR and TTR rays will be about 2/3 the larger deviation (that of the TTR). At the maximum range of 75 miles the ZEUS system is expected to have a miss distance standard deviation of 150 ft (compared to a kill radius of 800 ft against a shielded warhead). It would thus seem desirable to limit the error introduced by ray-bending to about 150 ft or 1/3 mil, thus allowing a TTR ray-bending of about 1/2 mil (0.03° or $1.7'$). Present calculations seem to indicate that at these altitudes the TTR bending will be less than this value, but further consideration of the effects of β-ray concentration by magnetic fields at high altitude is needed. In general, it is expected that position errors resulting from path-length variation (due to phase velocity changes) would be less than those due to angular displacements.

32. There appear to be large variations in estimated magnitude of auroral clutter and ARGUS noise, aside from the sensitivity of these effects to location. Perhaps the most ARGUS noise might reasonably be expected to do is to prevent full realization of the maximum ranges expected with the low-noise MASER amplifier of the TTR. Although both effects may be worse for the LAR and FAR, clutter effects, at least, are gated out by the same circuits that exclude meteors in the 50-75 mile altitude region.

33. We are not familiar with work done specifically on the degradation of radar data (e.g., interference with Chirp operation

27/ If both TTR and MTR rays were bent the same amount, missile and target would be brought together by the commend system with no final error resulting from the equal deviation of the beams.

or range accuracy) and possible system effects (e.g., interference with track-while-scan or analytic prediction) from the transient and perhaps fluctuating nature of the changes in the dielectric propagation media. Perhaps these are of importance only for a few seconds immediately after burst.

34. All our considerations above have been based on interference to NIKE-ZEUS from its own bursts. We would not expect such high-altitude bursts from enemy warheads unless it were with the deliberate intent of degrading the active defense (or some other military system depending upon electromagnetic phenomena).[28] Although the enemy surely would use higher yield bursts than that of the ZEUS warhead for such purpose, still the precise timing which appears to be required to make such a tactic effective, and the number required to overcome deployment factors, make it doubtful the enemy would place much reliance on such a measure.

35. In summary, it appears that nuclear effects as presently estimated would result in only moderate degradation of the ZEUS system from its own bursts under near-saturation conditions, and would be difficult for an enemy to utilize profitably. However, present estimates are subject to fairly large uncertainties of data and interpretation, being based on a few tests with incomplete instrumentation, and involving large numbers of competing phenomena whose relative importances are not fully understood. Thus any decisions of high confidence regarding ZEUS effectiveness in a nuclear environment must await results of further high-altitude nuclear tests. Consideration is being given to increasing the FAR and LAR frequencies, should the effects prove more serious than anticipated.

28/ Pointing out that such bursts can hamper or knock out electronic systems (BMEWS, communications) is not to say that they would have a high pay-off value to the enemy. It is pertinent here that high-altitude bursts against other systems would likely have little effect on ZEUS defense.

ESTIMATION OF ENGAGEMENT CAPACITY AND COVERAGE UNDER COUNTER-MEASURE CONDITIONS

36. If the engagement capacity and coverage of a fire unit (of given capability) against a threat (of given characteristics) can be determined, comparatively simple assumptions as to kill probability and salvo size will allow various measures of defense effectiveness to be applied. Early BTL studies considered engagement capacity from the standpoint of "multiplex" operation wherein the virtually unsaturable local acquisition radar furnished data for early missile guidance and the TTR's were required to track for only about 12 seconds immediately before intercept, giving a maximum TTR recycling time (including slewing to target, etc.) estimated as 24 seconds. Thus, with 3 TTR's per firing unit, an intercept could be made every 8 seconds. By permitting intercepts at maximum range on down to a minimum altitude, a certain number of ICBM's (up to perhaps 9, depending upon their ballistic coefficients and upon how much of their trajectories lay in the field of fire) arriving simultaneously could be engaged. As the time spacing of ICBM's was increased from zero (simultaneous) to 8 seconds (corresponding to the maximum-steady state engagement rate), the number of ICBM's a firing unit could handle (or the number of times the TTR's could be used before intercept took place below the minimum altitude) increased (from 9) to the limit imposed by the number of available missiles. In addition to carrying out a representative traffic analysis to determine these numbers, these studies also gave an approximate method for determining the expected number of ICBM's engaged in the practically important case of attack by a fixed number of ICBM's normally distributed with a given standard deviation in arrival time.[29] Perhaps the easiest way to improve on this approximation method and to establish confidence limits would be Monte Carlo sampling with a digital computer. One approach in this direction is discussed in a following section.

29/ An example typical of such calculations gives a firing unit engagement capacity for 29 missiles in a Gaussian attack of one minute standard deviation.

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37. Such early studies ignored light decoys which would reduce maximum range (this might be justified for low re-entry angles and launch before discrimination), and assumed that heavy decoys would have to be engaged, thus diluting the effective engagement capacity. Later studies clearly recognize the complications which decoy countermeasures could introduce into the multiplex mode of operation as a result of the necessity for use of the TTR and slaved DDR for discrimination of light decoys outside the atmosphere and of heavy decoys inside the atmosphere. These complications increase the recycling times by varying amounts on the one hand and reduce the number of decoys which have to be engaged on the other. Obviously a traffic analysis of n ICBM's normally distributed in arrival time, each accompanied by decoys, becomes a complicated affair. However, approximate analyses can still be made for the simpler cases of simultaneous arrival and constant rate (steady state) arrival, and something can be said about cases of nearly simultaneous arrival. For these purposes it is convenient to discuss separately the following two cases: (1) ZEUS Models A and B (these are considered together because they have similar engagement capacities and coverages with respect to objects fired on -- they differ in that Model A will waste missiles on some heavy decoys, whereas a successful Model B will not), and (2) ZEUS Model C with precursor burst discrimination (or other discrimination means which must be brought near the enemy missile). For each of these cases, launch before discrimination is considered standard operating procedure. However, the reduced capabilities of launch after discrimination will be discussed as a matter of interest and a simpler starting point, giving a lower limit on effectiveness parameters.

ZEUS Models A and B

38. When launch is delayed until re-entry discrimination is completed, TTR recycle time consists of about five seconds slewing, four seconds smoothing, eight seconds tracking for

discrimination, with the remainder being determined by the time of flight of the salvo to intercept. For heavy decoys, intercepts can be made out to 10 to 25 miles radius, with the larger radius corresponding to slow re-entry ICBM's (Threat Model A) and IRBM's (Threat Models C and D), and the smaller radius corresponding to fast ICBM's (Threat Model B). Discrimination comes so late (around 200,000-foot altitude) that only with slow re-entry bodies, if at all, can the TTR's be used more than once against simultaneous decoy clouds to intercept at acceptable altitudes. Thus a minimum simultaneous engagement capacity of three is indicated for a standard firing unit. However, there is a separation time, less than the recycle time,[30] for which objects following the initial "simultaneous" group can still be intercepted above minimum acceptable altitude of intercept (often taken to be 30,000 feet). Thus for "nearly simultaneous" clouds (and perhaps for cluster warheads of large extent), a "nearly simultaneous" engagement capacity of six can be attained in some cases. The steady state engagement capacity for intercepting slow ICBM's at 25-mile range would be about one every twelve seconds (corresponding to a recycle time of 35 seconds); for fast ICBM's at 10-mile range, one every 9 seconds (28 seconds recycle time).

39. For the normal situation of launching before discrimination, time of launch and trajectory can be selected so that, for the latest expected discrimination time of the nearest object in a cloud (corresponding to the lowest expected discrimination altitude of this object -- e.g., 200,000 feet for $\beta = 20$), the salvo

30/ This separation time is less than the recycle time by the time required for the object to travel from earliest possible intercept to minimum acceptable altitude. This latter time is thus dependent upon a traffic analysis as well as ZEUS and threat model characteristics. It is important in calculations assuming a distribution of arrival times, and we shall denote it as "engageable" time υ.

will have 15 seconds maneuver time after discrimination and before possible intercept of the object, assuming it had infinite ballistic coefficient (no slow-down). The 15 seconds will allow coverage of a cloud of at least 25 miles diameter anywhere within the 75-mile maximum range.[31] For actual warheads of finite β, somewhat more than 15 seconds may occur between discrimination and intercept, allowing a slightly larger coverage and higher intercept (depending on geometry).

40. Recycle time for this normal situation would be about 32 seconds (5 + 4 + 8 + 15), or not greatly different from that of the launch after discrimination case; in fact, for most threats, the two cases are the same in the "unrestricted" area around the battery. Thus again there would be no opportunity for a second chance at objects in a simultaneous threat except perhaps for slow re-entry bodies or IRBM's (especially at low angles). Again there is a "reservoir" time which determines how nearly simultaneous the threat must be before a nearly simultaneous engagement capacity of six can be achieved. The steady state engagement capacity would be roughly one every ten seconds as before. However, for the area outside that immediately around the firing unit (and up to 75-mile radius), attainment of the nearly simultaneous engagement capacity of six, as well as the above steady state rate, are dependent upon restricting salvos to less than three missiles or increasing the MTR:TTR ratio to allow multiplex operation.

ZEUS Model C

41. A ZEUS Model C which could successfully discriminate decoys outside the atmosphere using radar signature without precursor burst or other missile aids could more nearly approach the engagement capacities and 75-mile coverage radius calculated in the early

31/ Except that when these coverages are on either flank of the firing unit, they are squeezed in the flank dimension.

studies for the case of no decoys. It would fall short of these in an extended high-level attack, however, to the extent that "tying up" the TTR's for decoy discrimination outside the atmosphere increased the average recycling time. For a less extended or simultaneous attack in which all decoys could be discriminated by the time it became necessary to use the TTR for final tracking before 75-mile intercept,[32/] the engagement capacities and 75-mile coverage radius of the early studies could be realized.[33/] We have seen, however, that such discrimination methods probably can be defeated by balloon decoys.

42. Should out-of-atmosphere discrimination by precursor burst or other missile aids prove to give high confidence discrimination, these would prove equally as effective as the radar signature method of the preceding paragraph in maximizing the simultaneous or nearly simultaneous engagement capacities. This is again because discrimination could be accomplished beyond the range[34/] required to assure 75-mile maximum range intercept, allowing the TTR to achieve a recycling time of 24 seconds (uncomplicated by further discrimination requirements) to be employed over a time "reservoir" determined by the time required for the simultaneous objects to travel from altitude of initial engagement to minimum acceptable intercept (with multiplex operation to place missiles in proper trajectories prior to take-over by guidance from TTR data). The steady state engagement capability would again be comparable to that of the preceding paragraph, assuming that the final TTR

32/ This time would correspond to a range of about 300 miles for launch after discrimination, 125 for launch before discrimination in the ICBM case, and to lesser ranges corresponding to the lesser speeds in the IRBM case.
33/ This again assumes adequate MTR's (depending upon the number of missiles per salvo) to allow multiplex operation.
34/ Precursor burst is possible to 400-mile maximum range of missile. As in footnote 31, it might be required out to 125 or 300 miles. For ICBM, this requires detection by LAR or FAR at 500 or 1200 miles respectively.

guidance time for the precursor burst plus the subsequent discrimination time is comparable to that of the radar signature alone case. However, it is not now apparent that this kind of out-of-atmosphere discrimination can be developed into such a high-confidence method that missiles could be used effectively without waiting for re-entry discrimination.

ZEUS Model D

43. As long as re-entry phenomena constitute the most reliable sources of discrimination, it would appear reasonable to use out-of-atmosphere techniques (including precursor bursts) in the initial stage of an attack (before re-entry phenomena are available). Thereafter, these out-of-atmosphere techniques might be used only whenever TTR's were not tied up with re-entry discrimination, unless the initial use showed that an appreciable number of decoys were eliminated which would not have been eliminated upon re-entry (as could be the case with heavy decoys whose signature matched in but not out of the atmosphere). Assuming that the out-of-atmosphere discrimination leaves enough undiscriminated objects that we must await re-entry discrimination before committing missiles to targets, the chief advantages of Model C would be to eliminate decoys which might not be eliminated by Models A or B. This would not increase engagement capacity as we have been using the term (i.e., to indicate the number of objects which can be taken under fire), but would make ZEUS Model C more effective than Model B in the same way that B is more effective than A -- by reducing the number of undiscriminated decoys among the objects fired on. Thus Model C would take some of the burden off re-entry discrimination as well as complicate the enemy's decoy problem. This composite use of Models A, B, and C in such a realistic way we have called Model D.

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REPRESENTATIVE NIKE-ZEUS SIMULATION MODEL

44. Having discussed the general behavior of several ZEUS capability models as related to several threat models or types of threats, we can now select a simulation model of the NIKE-ZEUS firing unit in action against incoming enemy missiles and decoys with some confidence as to its applicability. It would have been more satisfying to have carried out more extensive and precise calculations for a number of the interesting situations defined in the preceding sections, but for the purposes of this project the discussion given is perhaps sufficient to allow the selection of parameter values for a simplified simulation model which can give a reasonable approximation as to realistic behavior as well as it can now be foreseen.

45. The simulation model assumed has been coded for the IBM-650, using a random sampling procedure. It applies to a number of incoming enemy missiles, each with or without non-discriminable decoys (for the case of decoy clouds), or each consisting of one or more warheads (for the case of cluster warheads). Arrival of a single missile and its decoys, or of the elements of a single cluster-warhead missile, is assumed simultaneous. Missile arrival times are assumed to be a random sample from a normal distribution.

46. The following three constants are assumed for the system:

a. Recycle time μ. This is the average minimum time required by the TTR (and slaved DDR) between successive salvo intercepts, and includes slewing, smoothing, tracking for discrimination and analytic prediction, and delay between individual missiles of a salvo.

b. Engageable time τ. This is the time during which a single warhead or non-discriminable decoy can be engaged, beginning with earliest possible intercept (considering

discrimination decisions which must be made), and ending with attainment of a minimum acceptable altitude. Detailed application would require what has been referred to previously as traffic analysis (including position and specification of enemy trajectories); for our purposes we have used a constant value of υ.

c. Standard deviation of arrival times σ. This is the standard deviation of the normal distribution of arrival times.

47. The simulation then examines a large number of samples of random normal deviates of a given size to determine the proportion of samples in which a penetration occurs. Penetration occurs when a missile, or portion of the elements of a missile (e.g., a warhead among several non-discriminable decoys), is engageable for time υ but is not engaged. Engagement of a missile element occurs if the time of arrival of the element, plus engageable time υ is not less than the time of the last previous engagement plus recycle time μ for all TTR's of the firing unit. No tracking time is assumed to be expended on a missile that cannot be engaged. In view of the approximation of constant υ (which actually varies with coverage), and the fact that whether their coverages overlap or not, all fire units of a Local Defense Center will be controlled from that center, it seems reasonable to treat penetration of coverage of several fire units as simply involving the total number of TTR's controlled according to the same engagement rules as for a single fire unit.

48. Some results of this simulation are presented in Figures 1-3. for several values of the parameters $\frac{\mu}{\sigma}$ and $\frac{\upsilon}{\sigma}$. The curves show the probability P of penetration as a function of sample size (number of attacking missiles). One sigma confidence limits are shown, based on the binomial distribution, for 50 samples, with standard deviation $\sqrt{50\ P\ (1-P)}$.

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FIGURES 1 AND 2

PROPORTION OF PENETRATIONS FOR VARIOUS SIZES OF MISSILE ATTACKS, WITHOUT CLUSTER WARHEAD OR NON-DISCRIMINABLE DECOYS, AGAINST ONE BATTERY

FIGURE 3

PROPORTION OF PENETRATIONS FOR VARIOUS SIZES OF MISSILE ATTACKS, WITH 3-ELEMENT CLUSTER OR 2 NON-DISCRIMINABLE DECOYS, AGAINST ONE BATTERY

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9-9-59-2

PROPORTION OF PENETRATIONS FOR VARIOUS SIZES OF MISSILE ATTACKS, WITHOUT CLUSTER WARHEAD OR NON-DISCRIMINABLE DECOYS, AGAINST ONE BATTERY

Normal Distribution of Incoming Missiles   Estimates and Estimated One-Sigma Limits Shown

For Definition of μ, σ, ν, and the Model Assumed, See Text

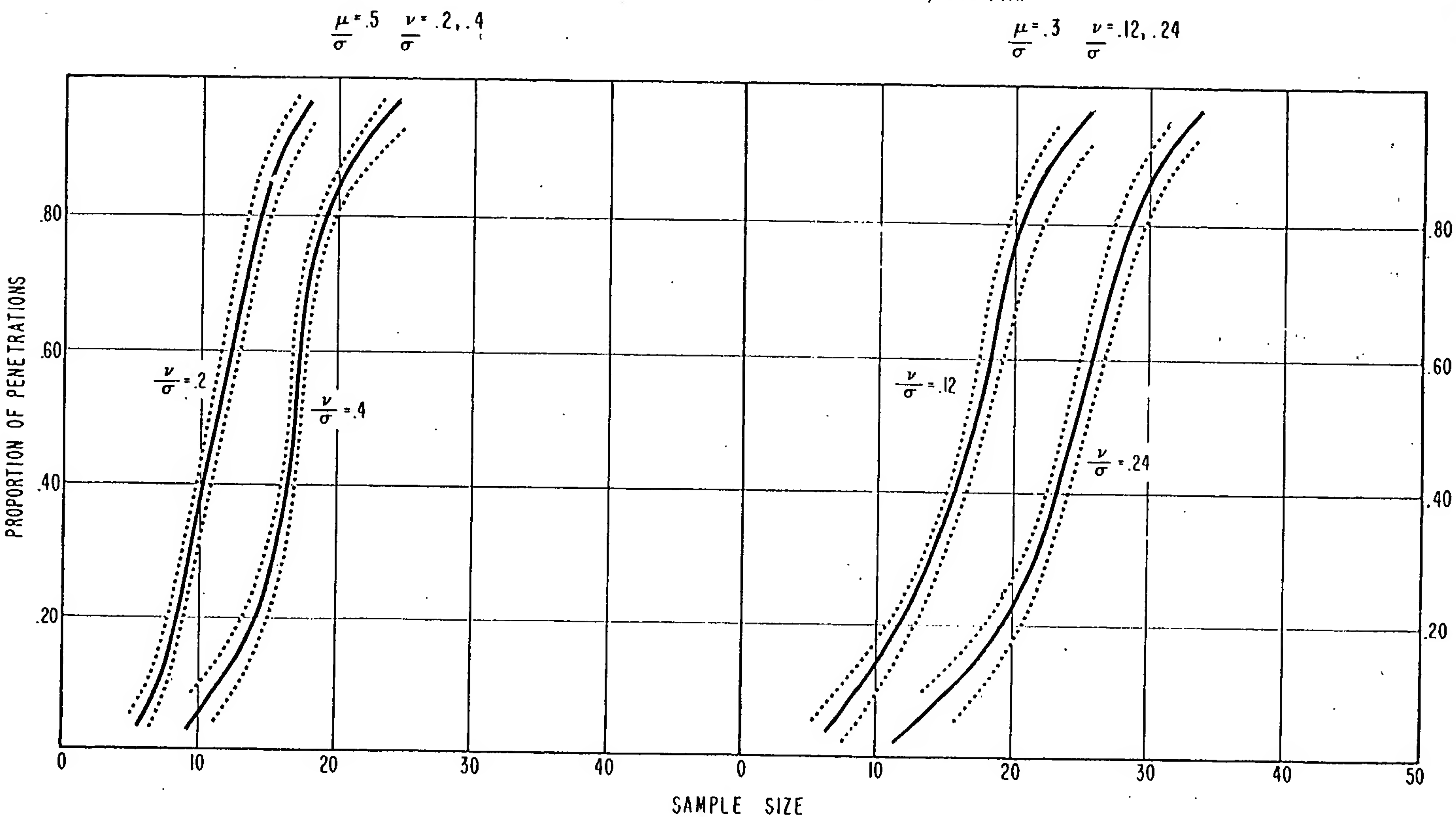

FIGURE 1
ENCLOSURE "D"
WSEG REPORT NO. 45

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9-9-59-3

PROPORTION OF PENETRATIONS FOR VARIOUS SIZES OF MISSILE ATTACKS, WITHOUT CLUSTER WARHEAD OR NON-DISCRIMINABLE DECOYS, AGAINST ONE BATTERY

Normal Distribution of Incoming Missiles   Estimates and Estimated One-Sigma Limits Shown

For Definition of μ, σ, ν, and the Model Assumed, See Text

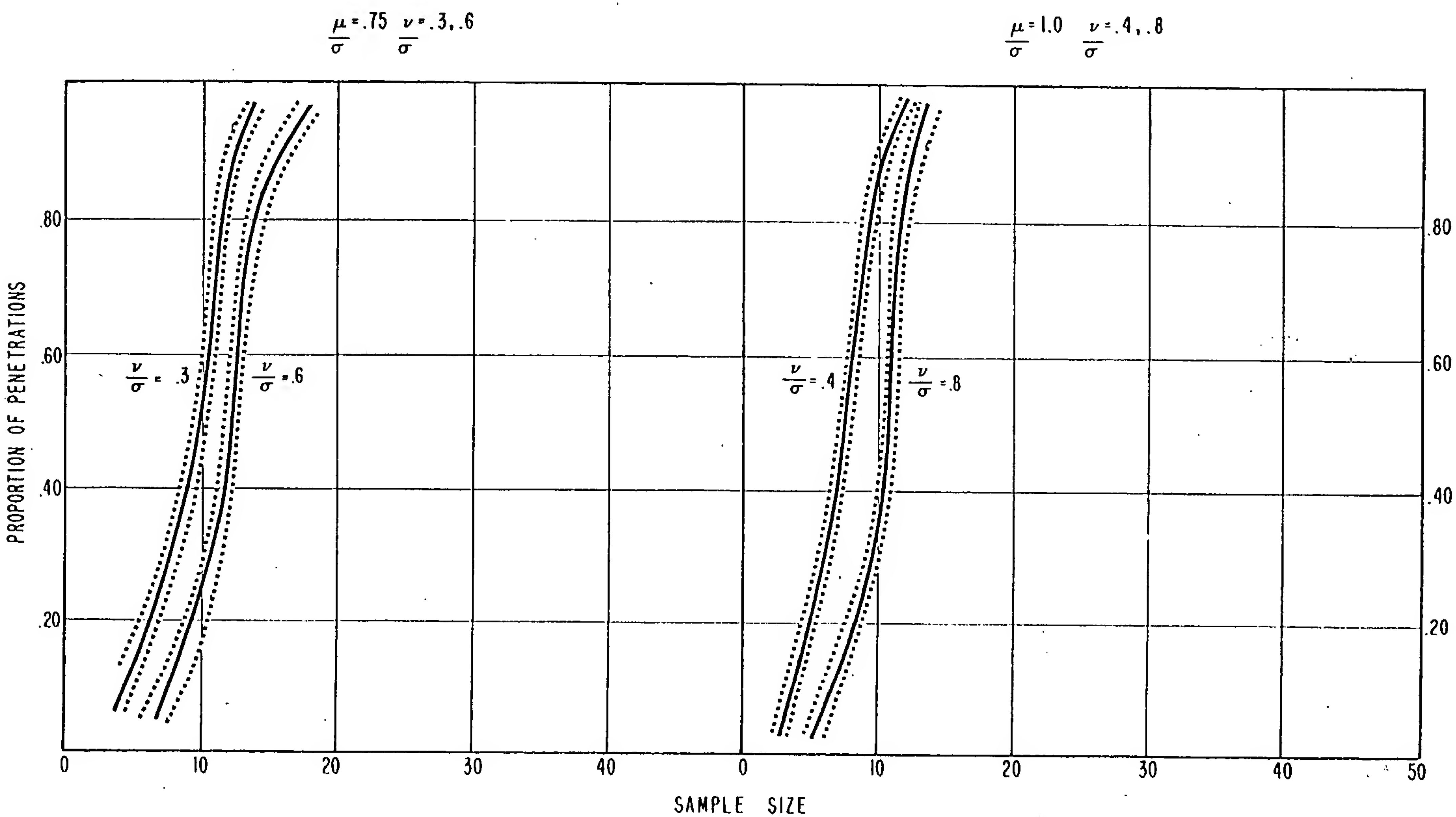

FIGURE 2
ENCLOSURE "D"
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9-9-59-4

PROPORTION OF PENETRATIONS FOR VARIOUS SIZES OF MISSILE ATTACKS, WITH 3-ELEMENT CLUSTER OR 2 NON-DISCRIMINABLE DECOYS, AGAINST ONE BATTERY

Normal Distribution of Incoming Missile   Estimates and Estimated One-Sigma Limits Shown

For Definition of μ, σ, ν, and the Model Assumed, See Text

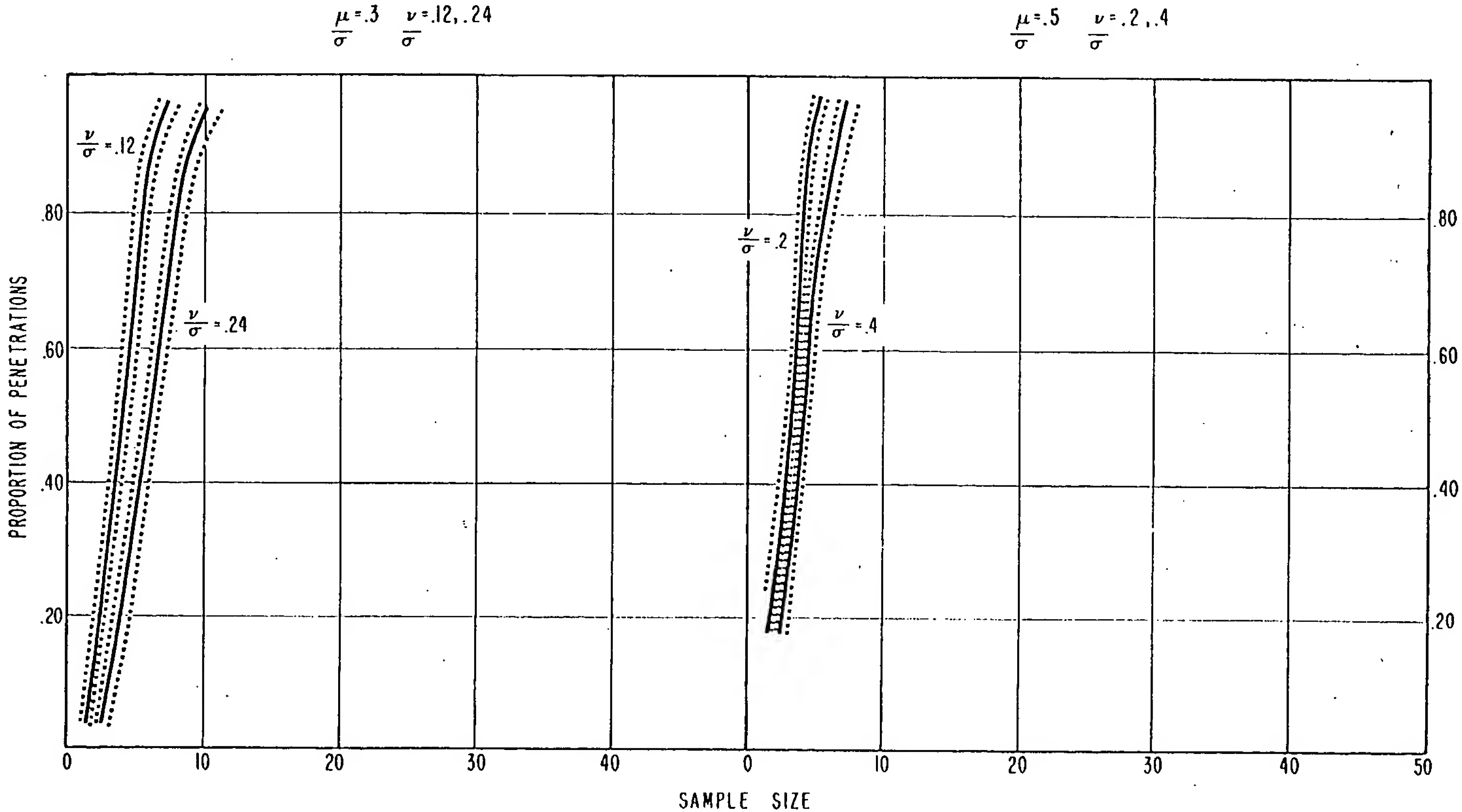

FIGURE 3
ENCLOSURE "D"
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49. In this project, values of δ - 1 minute, μ - 30 seconds, and υ = 12 seconds have been chosen to illustrate results of various attacks. This value of υ is fairly insensitive to threat characteristics, and is probably quite realistic. The value of υ (taking minimum acceptable altitude as 30,000 feet) appears to be a gross average over possible re-entry angles for a slow type warhead (Threat Model A) or for IRBM's (larger values might be obtained for the shorter range IRBM's). For intermediate and fast warheads, the value of υ would only be several seconds; however, the approximation of constant value of μ is very poor in these cases both because of variation with re-entry angle and variation between the areas adjacent to the fire unit and the area further removed toward maximum range. For this latter area, it is even doubtful that intercept can be made on fast re-entry bodies above 30,000 feet without reducing the volume of the cloud that can be covered; however, we have not made the necessary calculations to determine this. It should perhaps be recalled that, in order to be realistic, we have given ZEUS out-of-atmosphere decoy discrimination facilities no capability for increasing either range of intercept or number of objects which can be engaged, thus limiting its value to assisting re-entry discrimination in reducing the number of decoys which cannot be discriminated.

50. The chosen values of δ = 1 minute, μ = 30 seconds, and υ = 12 seconds, when applied to the simulation model, lead to estimates of the price in missiles to the attacker to penetrate a NIKE-ZEUS firing unit. For an attack by missiles without cluster warheads or undiscriminated decoys, 90 per cent probability of penetration is achieved with about 17 missiles. If the three sub-warheads of a 3-element cluster arrive simultaneously (or if a warhead arrives simultaneously with two undiscriminated decoys)

90 per cent probability of penetration of at least one warhead is achieved with 5 missiles. For these cases the "price" is defined as 16 and 4 respectively, these being the increase in cost (in number of missiles) of 90 per cent penetration probability which NIKE-ZEUS imposes, over the cost of NIKE-ZEUS does not defend the area penetrated. Similarly, the figure of 28 missiles obtained in Enclosure "C", for an attack using no saturation techniques, to give 90 per cent penetration probability, corresponds to a price of 27 missiles.

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TABLE II

PROBABILITY OF ACHIEVING 5 AND 100 PSI AT AIM POINT (SURFACE BURST)

Standard Deviation of Delivery Error	Yield	Probability of 5 psi	Probability of 100 psi
6,000 Feet	1 MT	.95	.14
	2 MT	.99	.21
	4 MT	1.0	.32
	8 MT	1.0	.45
12,000 Feet	1 MT	.54	.04
	2 MT	.68	.06
	4 MT	.87	.10
	8 MT	.96	.14
18,000 Feet	1 MT	.30	.01
	2 MT	.42	.03
	4 MT	.59	.04
	8 MT	.75	.07
24,000 Feet	1 MT	.19	.00
	2 MT	.27	.01
	4 MT	.39	.02
	8 MT	.54	.04

(S) 26. Let us suppose that P_i is the probability that the NIKE-ZEUS system will not be penetrated by the i-th incoming enemy missile, for a given NIKE-ZEUS firing doctrine. We also suppose that penetration is equivalent to destruction of the NIKE-ZEUS site. We have P_i = .992, or .96 or .80 if the i-th NIKE-ZEUS salvo is a 3-, 2-, or 1-missile salvo, respectively. Then Probability [shoot exactly k NIKE-ZEUS salvos] = Probability [k-th enemy missile penetrates and no previous missile penetrates] = $(1 - P_k)\ (P_1\ P_2 \ldots P_{k-1})$ where we recall that the values P_i depend on the firing doctrine chosen. The

$[1-(.20)^1] = .80$

$[1-(.20)^2] = .96$

$[1-(.20)^3] = .99$

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expected number of salvos fired by NIKE-ZEUS is then $\sum_k k\,(P_1 \dots P_{k-1})\,(1 - P_k)$ where k is summed over all P_i for which $P_i \neq 0$, that is, to the point where all the missiles are fired.

27. Suppose that the firing doctrine chosen is the one that will maximize the value of s for which $P_1 \dots P_s \geq .10$, that is, a doctrine maximizing the cost to the enemy of 90 per cent assurance of penetration. This doctrine will require the use of at least 48 of the supply of 50 missiles in the first s salvos, as shown below. Let $P_k = 1-(.2)^{i_k}$, where $i_k = 1$, 2, or 3. We will assume $1-(.2)^3 \approx 1.0$ and consequently, for the desired maximum value of s, if $P_1 \dots P_s \geq .10$, then $P_1 \dots P_{s+1} \geq .10$, $P_{s+1} \approx 1.0$ (i.e. $i_{s+1} = 3$). Consequently, we may suppose $\sum_{k\,i}^{s} i_k \geq 48$. Also, we suppose $i_j \leq i_k$ for $j \geq k$, since we wish to keep the probability of penetration with k missiles as small as possible within the confines of the firing doctrine.

28. We obtain then $P_1 \dots P_s = (.992)^b\,(.96)^{c-b}\,(.8)^{s-c} \geq .10$, where $3b+2(c-b) + (s-c) \geq 48$. We fire b salvos of 3 missiles each, then $c-a$ salvo of 2 missiles each, and $s-c$ salvos of 1 missile each. A little hand calculation with this formula, using Table III, shows that the maximum number of enemy missiles required to obtain 90 per cent probability of penetration is 28. The firing doctrine consists of 22 salvos of 2 missiles each and 6 salvos of 1 missile each. The probability of penetration in the first 28 shots is $1-(.96)^{22}\,(.8)^6 \approx .90$ The probability of penetration on the 29th shot is 1.0, because no missiles remain to be fired.

29. Similarly, if we wish to choose a doctrine maximizing the number of enemy missiles required to obtain 50 per cent probability of penetration, a little hand calculation from Table III

shows that we must use 6 salvos of 3 missiles, and 16 salvos of 2 missiles. Again, the total required for 50 per cent and 100 per cent probability of penetration differs by one, being 22 and 23 respectively. We might note that if the firing doctrine maximizing the number required for 90 per cent probability of penetration is chosen, then 50 per cent probability of penetration is achieved with the 17th enemy missile.

TABLE III

VALUES OF x^k FOR VARIOUS x AND k

	$(.992)^k$	$(.96)^k$	$(.8)^k$
k = 1	.992	.96	.8
2	.984	.92	.64
3	.976	.88	.51
4	.968	.85	.41
5	.96	.815	.33
6	.95	.78	.26
7	.945	.75	.21
8	.94	.72	.17
9	.93	.69	.13
10	.92	.66	.11
11	.915	.64	.09
12	.91	.61	.07
13	.90	.59	.06
14	.89	.56	.045
15	.89	.54	.04
16	.88	.52	.03
17	.87	.50	.03
18	.87	.48	.02
19	.86	.46	.01
20	.85	.44	.01
21	.84	.42	.01
22	.84	.41	.01
23	.83	.39	.01
24	.83	.37	.00

30. Which, if any, of the three firing doctrines examined here might be chosen by a NIKE-ZEUS battery could depend on

expected number of salvos fired by NIKE-ZEUS is then

$\sum_{k} k\,(P_1 \ldots P_{k-1})\,(1 - P_k)$ where k is summed over all P_i for which $P_i \neq 0$, that is, to the point where all the missiles are fired.

S 27. Suppose that the firing doctrine chosen is the one that will maximize the value of s for which $P_1 \ldots P_s \geq .10$, that is, a doctrine maximizing the cost to the enemy of 90 per cent assurance of penetration. This doctrine will require the use of at least 48 of the supply of 50 missiles in the first s salvos, as shown below. Let $P_k = 1-(.2)^{i_k}$, where i_k = 1, 2, or 3. We will assume $1-(.2)^3 \approx 1.0$ and consequently, for the desired maximum value of s, if $P_1 \ldots P_s \geq .10$, then $P_1 \ldots P_{s+1} \geq .10$, $P_{s+1} \approx 1.0$ (i.e. $i_{s+1} = 3$). Consequently, we may suppose $\sum_{k}^{s} i_k \geq 48$. Also, we suppose $i_j \leq i_k$ for $j \geq k$, since we wish to keep the probability of penetration with k missiles as small as possible within the confines of the firing doctrine. S

S 28. We obtain then $P_1 \ldots P_s = (.992)^b\,(.96)^{c-b}\,(.8)^{s-c} \geq .10$, where $3b+2(c-b) + (s-c) \geq 48$. We fire b salvos of 3 missiles each, then $c-a$ salvo of 2 missiles each, and $s-c$ salvos of 1 missile each. A little hand calculation with this formula, using Table III, shows that the maximum number of enemy missiles required to obtain 90 per cent probability of penetration is 28. S The firing doctrine consists of 22 salvos of 2 missiles each and 6 salvos of 1 missile each. The probability of penetration in the first 28 shots is $1-(.96)^{22}\,(.8)^6 \approx .90$ The probability of penetration on the 29th shot is 1.0, because no missiles remain to be fired.

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16	.88	.52	.03
17	.87	.50	.03
18	.87	.48	.02
19	.86	.46	.01
20	.85	.44	.01
21	.84	.42	.01
22	.84	.41	.01
23	.83	.39	.01
24	.83	.37	.00

30. Which, if any, of the three firing doctrines examined here might be chosen by a NIKE-ZEUS battery could depend on

the estimate made of the enemy's intentions, as well as on the nature of the target.

31. If the target is soft for example, and it is estimated that the number of missiles that will be sent against the target is small, salvos of three missiles may be used. If it is thought that the enemy wishes to insure penetration of the target, and will devote as many missiles as necessary to that task, then a salvo scheme similar to the one maximizing the number of enemy missiles necessary to achieve 90 per cent probability of penetration could be chosen.

32. The expected aim point of the enemy missile is also a factor. If the targets protected by NIKE-ZEUS are hard, and the incoming enemy missiles are not aimed close to vulnerable portions of the NIKE-ZEUS battery, then the firing doctrine of one NIKE-ZEUS missile for each enemy missile might be chosen to maximize the expected effectiveness of each NIKE-ZEUS missile. Because of this tactic, if the targets are numerous, and hard, the best enemy strategy would appear to be to attempt destruction of the defending battery before going after the hard targets. Since the enemy probably cannot operate under a shoot-look-shoot doctrine he must expend enough missiles on the battery to insure a high probability of penetration and destruction.

33. The analysis in this section has ignored the possible enemy capability in decoys, cluster warheads, and closer spacing of incoming missiles to attempt traffic saturation, and represents an upper bound on the enemy's penetration requirements. Attempts to achieve traffic saturation could greatly reduce this bound.

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34. Enclosure "D" gives a discussion of the traffic-handling capabilities of NIKE-ZEUS under various attack conditions. A computing machine simulation of a NIKE-ZEUS battery, described in Enclosure "D", shows the force levels required to saturate the system. For example, 17 missiles whose delivery times are normally distributed with one minute standard deviation, arriving against a battery which requires 30 seconds from engagement to engagement, and which can terminate successful engagement only during a 12-second enemy flight time, will have a 90 per cent probability of at least one weapon down on target. If each missile arrives together with two non-discriminable decoys, only 5 missiles will be required to achieve 90 per cent probability of one successful missile on target.

(U) 35. These reduced force levels illustrate clearly the value to be gained by the use of traffic saturation techniques and non-discriminable decoys, or cluster warheads. Reduction in force levels necessary to achieve a certain degree of damage to the NIKE-ZEUS system can be very large, if the enemy has the necessary techniques in missile development and launch coordination.

DEFENSE OF THE MINUTEMAN AND OTHER MISSILE SYSTEMS

MINUTEMAN

(U) 36. A discussion of possible 1965 force levels in MINUTEMAN missiles has been given in paragraph 5, together with the characteristics of the system. This system is expected to comprise a large portion of the U.S. retaliatory force at this time, and its hardness makes it relatively invulnerable to attack. A possible use for NIKE-ZEUS batteries might be to provide protection for a large number of hardened MINUTEMAN missile sites. We will investigate the potential effectiveness of this use in this section.

37. The MINUTEMAN missile is planned to have a reaction time of . that is, it can be launched after signal-to-launch. However, because the missile is not recallable in case of an unjustified launching, the decision to launch may not be left to low level personnel, and may have to await a signal that arrives some time even after an attack on MINUTEMAN sites has begun. For strategic purposes, also, it may be desirable to reserve some missiles for the threat of later use. In order to survive, these sites may have to endure attack by low altitude aerodynamic missiles and manned bombers.

38. Separation of MINUTEMAN missile sites is currently planned to be at least 4 n.mi. to prevent multiple kills from enemy weapons. With this spacing, a very large number of MINUTEMAN missile sites could be contained within the protective umbrella of one NIKE-ZEUS battery (if assumed to be 75 miles in radius). Of course other targets deserving protection could also be under this umbrella. However, in this section we will investigate only the potential usefulness of the NIKE-ZEUS system for defending MINUTEMAN.

39. Investment costs of the NIKE-ZEUS system, which exclude research and development and annual operating costs, are given in Appendix "A" of Enclosure "A". For the 120-battery program, available in about 1968, the cost of 9 FAR's, 35 LAR's and 120 batteries, excluding warheads, is given as approximately $11,540,000,000 or a battery-slice cost of about $96 million. If the FAR's are excluded from this cost. the per-battery-slice cost would be about $91 million. Costs for various MINUTEMAN missile programs are given in Enclosure "D" to the Second Annual Review of WSEG Report No. 23. The investment cost, which excludes research and development, warheads, and annual operating